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Feasibility of Elk Creek Acid Mine Drainage Abatement Project

Skelly and Loy, Harrisburg, Pa

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Industrial Environmental Research Lab, Cincinnati, Ohio

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A detailed study was conducted within the Elk Creek Watershed, West Virginia to determine the technical and economic feasibility of three acid mine drainage abatement techniques. Alkaline regrading and slurry trench construction were established as technically and economically viable abatement techniques at four of five potential demonstration project sites, while mine roof collapse was considered feasible at one location.

Alkaline regrading-reworking existing alkaline spoil material-is a method for improving neutralizing capabilities and facilitating slurry trench installation. The slurry trench abatement technique involves construction of an impervious underground dam in alkaline strip mine spoil to cause inundation with acid mine drainage and thus prolong neutralization. Collapsing abandoned deep mine entries results in partial mine flooding and exposes mine waters to alkaline roof material.

Backfilling and regrading practices associated with recent surface mining has produced significant water quality improvement in the Elk Creek Watershed. Demonstration of alkaline regrading, slurry trenching and mine roof collapse as viable abatement techniques will provide the technology for prolonging beneficial effects of current surface mining and facilitate elimination of acid discharge from abandoned mines.

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FEASIBILITY OF ELK CREEK

ACID MINE DRAINAGE ABATEMENT PROJECT

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FOREWORD

When energy and material resources are extracted, processed, and used, these operations usually pollute our environment. The resultant air, land, solid waste and other pollutants may adversely impact our aesthetic and physical well-being. Protection of our environment requires that we recognize and understand the complex environmental impacts of these operations and that corrective approaches be applied.

The Industrial Environmental Research Laboratory - Cincinnati assesses the environmental, social and economic impacts of industrial and energy-related activities and identifies, evaluates, develops and demonstrates alternatives for the protection of the environment.

This report is a product of the above efforts. It presents results of a detailed feasibility study to determine technical and economic mine drainage abatement techniques for abandoned underground coal mines. The methods found to be feasible were slurry trench construction, alkaline regrading and mine roof collapsing. Slurry trench construction is a novel approach to dam and direct underground mine water seeping through surface mine spoils. The acid water is directed to a highly alkaline backfill material where the acid is neutralized in place. Mine roof collapsing is another innovative technique for treating acid water in place. Where an alkaline strata exists above the coal seam, selected blasting is used to collapse the alkaline material into the acid stream.

This report will be of interest to individuals and control agencies involved in the design of abatement techniques to control acid mine drainage from abandoned mines. In some situations, it may have applications to active mine situations.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

This report presents results of a detailed feasibility study conducted within the Elk Creek Watershed, West Virginia. The purpose of this study was to determine the technical and economic feasibility of three acid mine drainage abatement techniques. Alkaline regrading and slurry trench construction were considered technically and economically feasible at four of the five individual locations, while mine roof collapse was considered feasible at one of the five sites. Alkaline regrading consists of reworking existing alkaline spoil material to improve neutralizing capabilities and facilitate slurry trench construction. The slurry trench abatement technique involves construction of an impermeable underground dam in alkaline strip mine spoil to cause inundation with acid mine drainage and thus prolong neutralization. Collapsing abandoned deep mine entries results in partial mine flooding and exposes mine waters to alkaline roof material.

Project efforts included: field investigations; soil analysis; water quality and quantity monitoring; bid package preparation and supervision of exploratory backhoe excavation; detailed mapping; and preparation of predesign engineering plans and cost estimates.

This report was submitted in partial fulfillment of Grant Project Number S-801273 by Skelly and Loy, Engineers - Consultants, under the sponsorship of the Environmental Protection Agency and West Virginia Department of Natural Resources. Work was completed on November 11, 1974.

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Special thanks is given to Sandy DeMark and other members of the Harrison County and Elk Creek Water Pollution Control Committee, Inc., for their assistance in initiating this study and continued efforts throughout the project.

SECTION I

CONCLUSIONS

1. Alkaline regrading, slurry trench construction and mine roof collapse are all viable acid mine drainage techniques within the Elk Creek Watershed.

2. Recorded flow data and chemical analyses indicate that Project Sites #1, 2, 3 and 4 discharge sufficient pollutant loadings to facilitate demonstration of proposed acid abatement techniques.

3. Based on gross estimates of spoil material surface area and soil tests, more than adequate alkalinity should be available for neutralization of acid mine drainage via inundation of strip mine spoil.

4. The quality of mine drainage emanating from Project Site #5 changed from net acidity to net alkalinity during this Feasibility Study. This site does not therefore, lend itself to demonstration of alkaline regrading and slurry trench construction.

5. An average acid loading of 1290 kg/day, (2844 lbs/day) is discharged from the five prospective demonstration sites.

6. The Pittsburgh crop coal must be strip mined and reclaimed in advance of abatement construction at Project Site #1 to provide necessary alkaline spoil material.

7. Aerial photography, 100' scale mapping and exploratory backhoe excavation will be required for Project Sites #1 and 2 following completion of surface mining.

8. Abatement construction will provide both water quality and aesthetic benefits to the Elk Creek Watershed.

SECTION II

RECOMMENDATIONS

1. The following priorities are recommended in selecting demonstration project sites:

Project Site (see Section VIII)		Estimated Cost
1) Site #4	-	$ 62,100
2) Site #2	-	173,000
3) Site #1	-	189,700
4) Site #3	-	171,300

2. Selection of demonstration sites and approval to proceed with the engineering design, construction and monitoring phases of this project are recommended.

3. Aerial photography, 100' scale mapping and exploratory backhoe excavation are recommended immediately upon completion of surface mining and regrading, if Sites #1 and 2 are chosen for demonstration of abatement techniques.

4. Monitoring of acid discharges and receiving streams should be continued at those sites selected for design and construction.

5. Settling ponds should be used during construction to control silt loadings into receiving streams. These ponds will also facilitate precipitation of ferric iron resulting from oxidation of mine drainage discharging through alkaline spoil within abatement construction areas.

6. It is recommended that the King Knob Coal Company be informed of any decisions concerning Project Site #1. They should also be encouraged to begin strip mining immediately following approval of the feasibility study.

SECTION III

INTRODUCTION

Degradation of water quality occurs in varying degrees with any coal mining operation. Water quality standards imposed upon active coal mining operations by federal and state legislation have effectively limited water pollution from these regulated mining activities. However, many coal mines that were abandoned prior to the imposition of stringent water quality standards continue to discharge large volumes of pollutants into receiving streams. Mine drainage pollutants can significantly degrade the quality of receiving streams, restricting public use of these waters. Thus, there is an urgent need to develop practical techniques to eliminate degradation of streams by mine drainage from abandoned mines.

A feasibility study was conducted to determine the feasibility and desirability of demonstrating a combination of three techniques for abating acid mine drainage from abandoned underground coal mines exposed by strip mining. Five individual pollution sources located within the Elk Creek Watershed near Clarksburg, West Virginia, were evaluated as potential abatement project construction sites. A combination of slurry trench construction and alkaline regrading was considered for four project sites, while mine roof collapse in conjunction with slurry trench construction and alkaline regrading was evaluated for the fifth project site.

This feasibility report culminates the first phase of a four phase demonstration project. The project phases are as follows: Phase I - Feasibility Study; Phase II - Engineering; Phase III - Construction; Phase IV - Monitoring. Except for the Monitoring, each phase will begin following approval of work from the preceding phase. The monitoring was initiated during the Feasibility Study to accumulate pre-construction water quality data. Bi-monthly monitoring will continue for one (1) year following completion of project construction. This will provide for evaluation of the project effectiveness.

The Elk Creek Watershed demonstration projects were funded by the U. S. Environmental Protection Agency through the West Virginia Department of Natural Resources under Section 14 of the Federal Water Pollution Control Act, following completion of a Pre-Feasibility Report for the Harrison County and Elk Creek Water Pollution Control Committee, Inc. Five demonstration project sites were selected

during the Pre-Feasibility Study. To insure investigation of the major pollution sources potential project site locations were selected from the Monongahela River Remedial Project Study Report. Field reconnaissance and water sampling was conducted at each possible location to determine the present extent of mine drainage pollution and the adaptability of proposed abatement construction at each particular locale.

This Feasibility Study was initiated, August 1, 1973, to evaluate implementation of abatement techniques at the five demonstration project sites selected during the Pre-Feasibility Study. Detailed field reconnaissance was conducted at each location with all pertinent information recorded. Major mine drainage discharges were located and water samples collected in conjunction with flow estimates. A water quality monitoring system was devised following evaluation of pollutant loadings. Monitoring stations were located on all major mine drainages emanating from each project site to determine the severity of pollutant production. Stations were also located above and below the confluence of mine discharges with major receiving streams to evaluate stream degradation from each project site.

Aerial photographs were used to produce detailed mapping of individual demonstration project areas. Pre-design plans and other pertinent features are illustrated on the detailed mapping. In addition to this site mapping, available mine maps were collected and contacts were made with persons familiar with the mines. Existing data concerning geology, climatology, coal production, hydrology, property ownership, the location of gas lines and wells, drilling and blasting and other information related to the study was collected.

Additional field investigations included backhoe excavation to obtain geologic data for designing the abatement construction and collecting samples of highwall and spoil materials. The sampled materials were analyzed at the West Virginia University soil testing laboratories to determine the neutralization potential ($CaCO_3$ equivalence).

Pertinent data and conclusions resulting from the Feasibility Study are included in this report. Pre-design specifications were developed to determine the construction cost estimates listed with engineering design discussions in this report.

SECTION IV

JURISDICTIONAL FRAMEWORK

COGNIZANT AUTHORITY

This study has been conducted under the auspices of the U. S. Environmental Protection Agency. The Agency is subject to the provisions of the Water Quality Improvement Act of 1970, PL 91-224. The Act includes a subsection titled "Area Acid and Other Mine Water Pollution Control Demonstrations" which became Section 14 of the Federal Water Pollution Control Act, as amended. This section provides for the demonstration of techniques for mine drainage pollution control and directs that the Environmental Protection Agency shall require such feasibility studies as necessary in selecting watersheds for the purpose of demonstration projects. Such feasibility studies are to aid the Environmental Protection Agency in selecting not only the mine drainage pollution control method(s), but also the watershed or drainage area for such application. The Act requires that the Environmental Protection Agency give preference to areas which will have the greatest public value and uses.

The Environmental Protection Agency, Office of Research and Monitoring, issued a Grant for the mine drainage demonstration project, described herein, to the State of West Virginia, Department of Natural Resources. Administration of the study has been the responsibility of the State of West Virginia's Department of Natural Resources.

The Department of Natural Resources is a statutory unit of the West Virginia government headed by a Director. The Department has the authority to exercise all state administrative functions relating to surface mining, reclamation of surface mined lands, and water pollution control in West Virginia. Such administration is performed through the Department's Division of Reclamation and the Division of Water Resources.

Full responsibility for the contractual agreement, administration and operation of the demonstration project rests with the Department of Natural Resources of the State of West Virginia; however, the Department may see fit to delegate the performance of some tasks to competent contractors.

Therefore, the present legal and administrative structure is adequate for conducting the project since all authority for water pollution control and reclamation of surface mined lands is now vested in the Department and its Divisions. This is covered by the foregoing jurisdictional authority and the pertinent sections of the law.

EXISTING AND PROPOSED STANDARDS

The site of the demonstration project is within the jurisdiction of the State of West Virginia. The streams involved are considered public streams of the State and are thereby subject to the most stringent of all applicable water quality standards imposed by the Federal Government and the State of West Virginia.

Present standards relative to wastewater discharges, including acid mine drainage to the Elk Creek Watershed, are subject to enforcement by the Division of Water Resources of the State of West Virginia. The general standards indicate the quality criteria for such waters, and are delineated in detail in Section 3 and 5 of the West Virginia Administrative Regulations.

Elk Creek, a tributary of the West Fork River, is subject to the specific water use and water quality applicable to the West Fork River, which are delineated in Sections 6 and 13 of Series II of the State's administrative regulations.

At the present time, the water quality standard for sulfates (see 13.01 b. 9. of the regulations) is not considered binding due to the current level of technology in sulfate removal and the cost effectiveness of such removal.

MINE DRAINAGE ABATEMENT TECHNIQUES

This project will demonstrate the use of a slurry trench as a Mine Drainage Abatement Technique. The primary purpose of the project is to determine, by monitoring, what effect the slurry wall will have on the individual mine discharges. The project will also include the monitoring of the receiving streams to determine how they are being affected by this particular technique.

SITE ACQUISITION

The site of the demonstration project is located within the boundaries

of the State of West Virginia. Authority is vested in the Chief of the Division of Water Resources to acquire land, as required, through the power of eminent domain as detailed by Section 11a of Article 5A, Chapter 20 of the Code of West Virginia, 1969.

The demonstration project includes five separate locations within the Elk Creek Watershed. The land is held in private ownership by several individuals and a few coal companies. The property owners for each of the stream monitor stations and abatement construction locations have been identified. Each of the stream monitor station property owners were contacted and a formal release was obtained for the installation of the monitor stations and associated structures. At this time, acquisition of releases for abatement construction has not been completed, releases from a few more owners are still required. The owners of the property are under no obligation to participate in such a project, except as the Division of Water Resources may have jurisdiction over the maintenance of the safety, health and welfare of the citizens of the State. Successful acquisition releases to perform the project tasks will preclude the necessitating of invoking the power of eminent domain.

WATER AND MINERAL RIGHTS

Property ownership and the associated title to the water and/or mineral rights in the Elk Creek Watershed area, designated site of the demonstration project, are of major concern with respect to project progress. Releases will be required from all owners of property upon which reclamation work will be performed, because it will involve regrading of spoil banks, construction of Slurry Wall, and revegetation of areas worked. Since the project is being conducted under the direction of the regulatory bodies of the State, it is anticipated that there will be no problem in obtaining releases and cooperation for such work, because it relieves owners and operators from such responsibility under the law.

Surface waters flowing through a property is generally considered as public water of the State of West Virginia. Ownership of this resource is, therefore, not a question since the project is being implemented by an agency of the State, who holds public ownership of same.

The Elk Creek demonstration sites are underlain with two major coal seams: the Pittsburgh, and the Redstone. Pittsburgh and Redstone seams are present and have been mined at all sites with the exception of Project Site #4, where the Redstone seam is not present. Mineral

rights to these coals are generally considered to be owned by the individual coal company involved.

No purchase of transfer of rights or ownership is expected for any portion of the project, since active mining operations will not be disturbed. All of the individual project sites represent abandoned drift and strip mines.

PREVENTION OF FUTURE POLLUTION

The Surface Mining Act and the Water Pollution Control Act of the State of West Virginia, administered by the Department of Natural Resources, provide the regulations necessary for land reclamation and rehabilitation with requisite mine drainage control measures, as well as the control and reduction of pollution in the State's waters.

The Water Pollution Control Act of the State of West Virginia (Article 5A, Chapter 20 of the Code of West Virginia, 1969, as amended) provides for pollution control and continuing jurisdiction over same as indicated by Sections 1, 3, 5 and 14 of the article.

The Water Resources Division has clear jurisdiction over control measures applicable to acid mine drainage, as defined within the Water Pollution Control Act. Therefore, at present and in the future, all State waters shall be subject to the control measures as given in Section 5, Series I, of the West Virginia Administrative Regulations and Chapter 20, Articles 5 and 5A of the Code.

The 1967 Surface Mining Act provides specifically for the prevention of future pollution and any and all sites in the State because of its provision governing reclamation procedures and administration. Specific regulations covering reclamation procedures and revegetation techniques and standards were established in Article 6, Chapter 20, of the Code of West Virginia in 1967, which are to be administered under the provisions of the aforementioned Act. Administration of the foregoing rests with the Director of Natural Resources, the Division of Reclamation and the Reclamation Commission, each of which has specific areas of responsibility with respect to the law, which are defined in detail in the Act.

The water infiltration control procedures outlined for implementation as a part of this project are in keeping with the laws and regulations established, and are applicable to any future work which might be re-

quired to overcome deleterious drainage effects upon the Elk Creek Watershed from adjacent property and workings. Such property and workings are also subject to the regulations now on the books and would be required to comply with same; otherwise they would risk the loss of permits granted, performance bonds posted and all fees paid.

The State of West Virginia assures the Environmental Protection Agency that it will exercise its authority under State statutes to provide legal and practical protection to the project area to insure against any activities which will cause future acid or other water pollution.

SECTION V

LOCATION AND AREA DESCRIPTION

PHYSIOGRAPHY AND GEOLOGY

The Elk Creek Watershed is 319 square kilometers (123 square miles) in area and lies east of the West Fork River in northcentral West Virginia (see Figure 1). Its drainage area includes portions of Harrison, Barbour and Upshur Counties. The community of Clarksburg is dissected by the northwest corner of the Elk Creek Watershed and represents the major population center within this watershed.

Elk Creek is augmented by numerous tributary streams as it flows northwest from Elk City to its confluence with the West Fork River at Clarksburg. Of these tributary streams, Stewart Run, Gnatty Creek, Brushy Fork and Nutter Run are all affected by mine drainage from proposed demonstration project sites (see Figure 2). Degradation of water quality in these tributaries is discussed in another portion of this report with respect to the pollution contributed from each project site.

The Elk Creek Watershed lies entirely within the Appalachian Plateau Province. A series of broad, low relief, northeasterly trending anticlines and synclines superimpose a rolling structure upon the northwesterly regional dip of the beds. This local structure, caused by the folding, controls ground water flow patterns within the watershed.

Most near surface ground water is conveyed via fractures, jointing and mine entries through overlying strata and mines in the Redstone coal seam into extensive underground coal mines in the pittsburgh coal seam. A relatively impermeable underclay associated with the Pittsburgh coal inhibits further infiltration. Thus, ground water is collected in abandoned deep mine workings, and flows from the mines along synclinal lows. Since the coal seams in this area contain acid producing iron sulfide minerals, many of the deep mine discharges are acid. However, large amounts of alkalinity are present in the overburden and, therefore, the strip mine spoil material has produced alkaline discharges from regraded strip mines on the perimeter of deep mine workings.

The Redstone and Pittsburgh coal seams of the Monongahela Series in

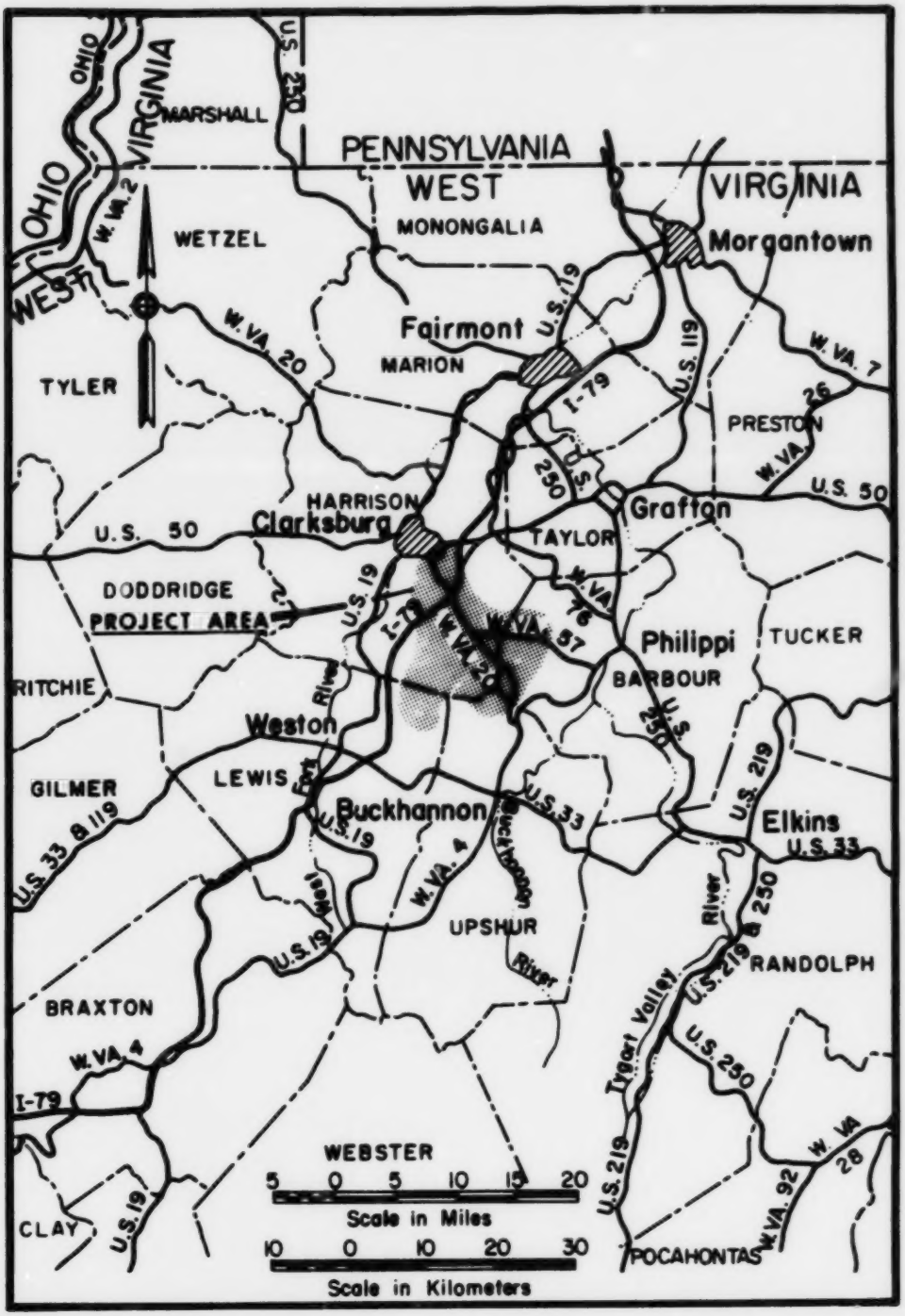


Figure 1. Location map for the Elk Creek project.

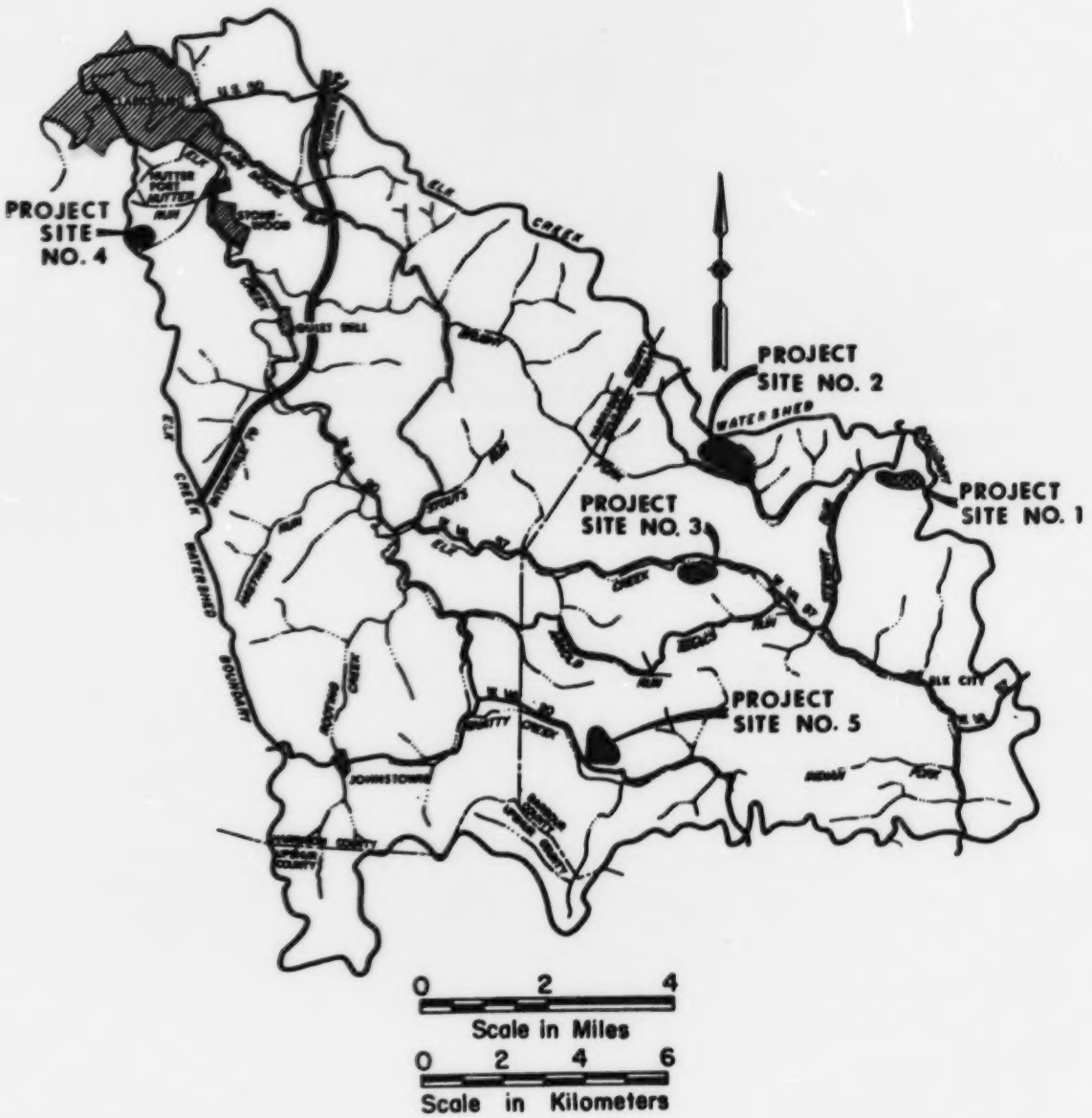


Figure 2. Elk Creek watershed map.

the Pennsylvania System are the only coals mined in the watershed with the exception of several local rider seams. The Monongahela Series has been eroded from two major anticlines in this area (Chestnut Hill and Hiram Anticlines), exposing the Conemaugh Series in northwestern portions of the watershed. Mining activity is thus confined to two northeasterly trending belts where the Monongahela Series has been preserved within synclinal troughs adjacent to major anticlines. A generalized stratigraphic column (see Figure 3) recorded at Project Site #2 is representative of stratigraphy through much of the Elk Creek Watershed. Both the Redstone and Pittsburgh coal seams vary in thickness. Pittsburgh Coal ranges from 1.2 to 3 meters (4 to 10 feet), and Redstone Coal ranges from 0.3 to 1.8 meters (1 to 6 feet). In addition, in the northwest section of the watershed Redstone Coal changes lithology from coal to a black shale. Limestone and clay (mudstone) units provide large volumes of alkalinity available in strip mine spoil for neutralization of acid waters. Specific geology and neutralization potential of spoil materials present are detailed in the site descriptions and evaluations.

MINING

Coal mining is one of West Virginia's largest industries with 21% of the Nation's total bituminous and lignite production in 1971 and 1972. Preliminary estimates show 112 million metric tons (123 million tons) of bituminous and lignite produced in West Virginia during 1972. Harrison and Barbour Counties average approximately 8% of the total coal production in the State. Data for 1971 indicates that the distribution of the Harrison and Barbour County production was 65% from underground, 34% from surface and 1% from auger mining. This high percentage contributed from underground mining partially reflects the existing problem from deep mine discharges.

CLIMATE

The National Weather Service maintains a recording station at Clarksburg. Average temperature and total rainfall are recorded daily. This information is published monthly by the National Oceanic and Atmospheric Administration. Figures 4 and 5 show monthly average temperature and total precipitation during the feasibility study in comparison with a thirty-one year mean temperature and normal precipitation. Records of this thirty-one year period show an annual mean temperature of 11.16 degrees centigrade (52.1°F.) and an annual precipitation normal of 102.08 centimeters (40.19 inches). This nor-

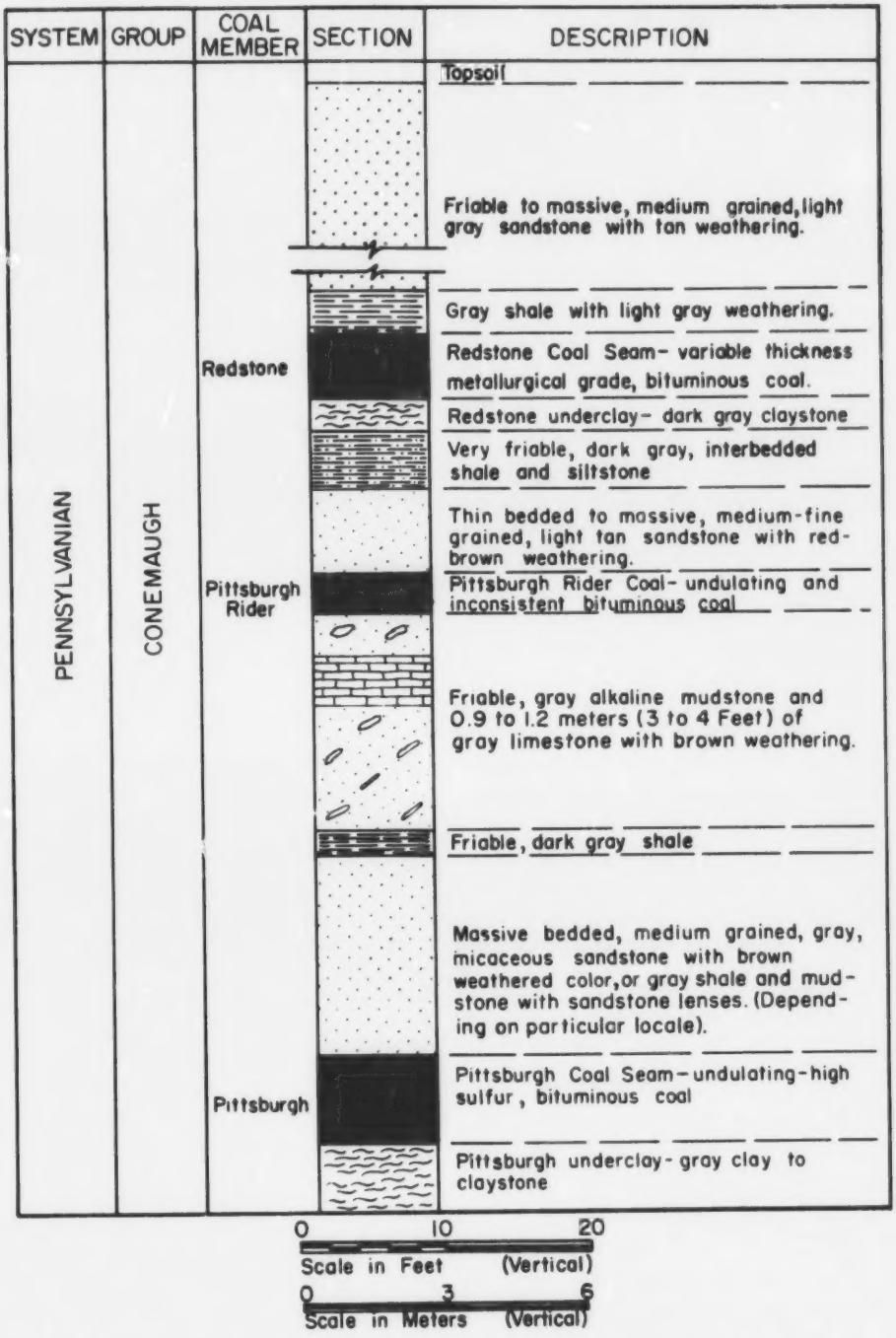

SYSTEM
GROUP
COAL MEMBER
SECTION
DESCRIPTION
PENNSYLVANIAN
CONEMAUGH
Topsoil
Friable to massive, medium grained, light gray sandstone with tan weathering.
Gray shale with light gray weathering.
Redstone
Redstone Coal Seam- variable thickness metallurgical grade, bituminous coal.
Redstone underclay- dark gray claystone
Very friable, dark gray, interbedded shale and siltstone
Thin bedded to massive, medium-fine grained, light tan sandstone with red-brown weathering.
Pittsburgh Rider
Pittsburgh Rider Coal- undulating and inconsistent bituminous coal
Friable, gray alkaline mudstone and 0.9 to 1.2 meters (3 to 4 Feet) of gray limestone with brown weathering.
Friable, dark gray shale
Massive bedded, medium grained, gray, micaceous sandstone with brown weathered color, or gray shale and mud-stone with sandstone lenses. (Depend-ing on particular locale).
Pittsburgh
Pittsburgh Coal Seam- undulating- high sulfur, bituminous coal
Pittsburgh underclay- gray clay to claystone
0 10 20
Scale in Feet (Vertical)
0 3 6
Scale in Meters (Vertical)

Figure 3. Generalized stratigraphic column for the Elk Creek area.

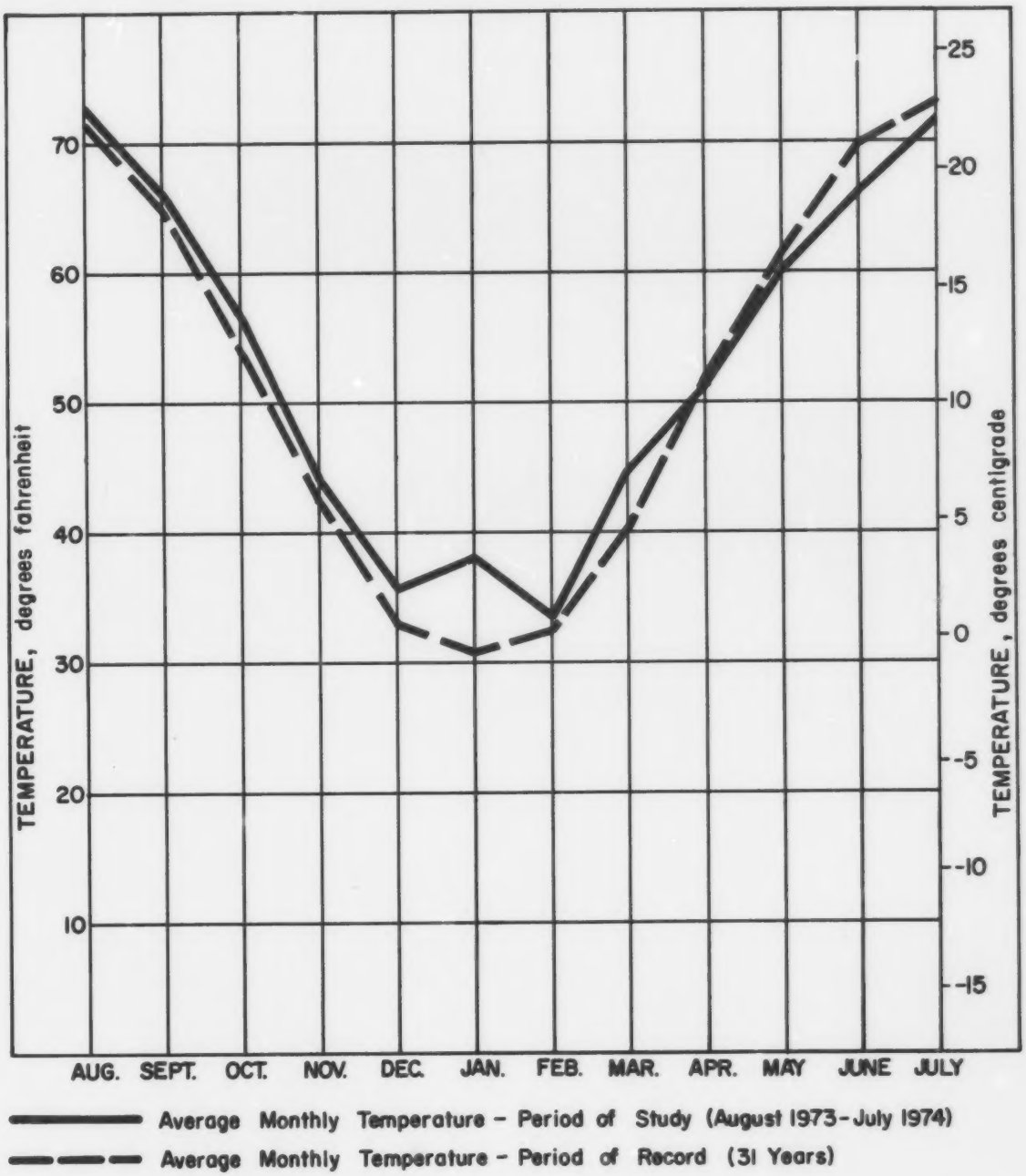


Figure 4. Monthly temperature as recorded by the Clarksburg weather station.

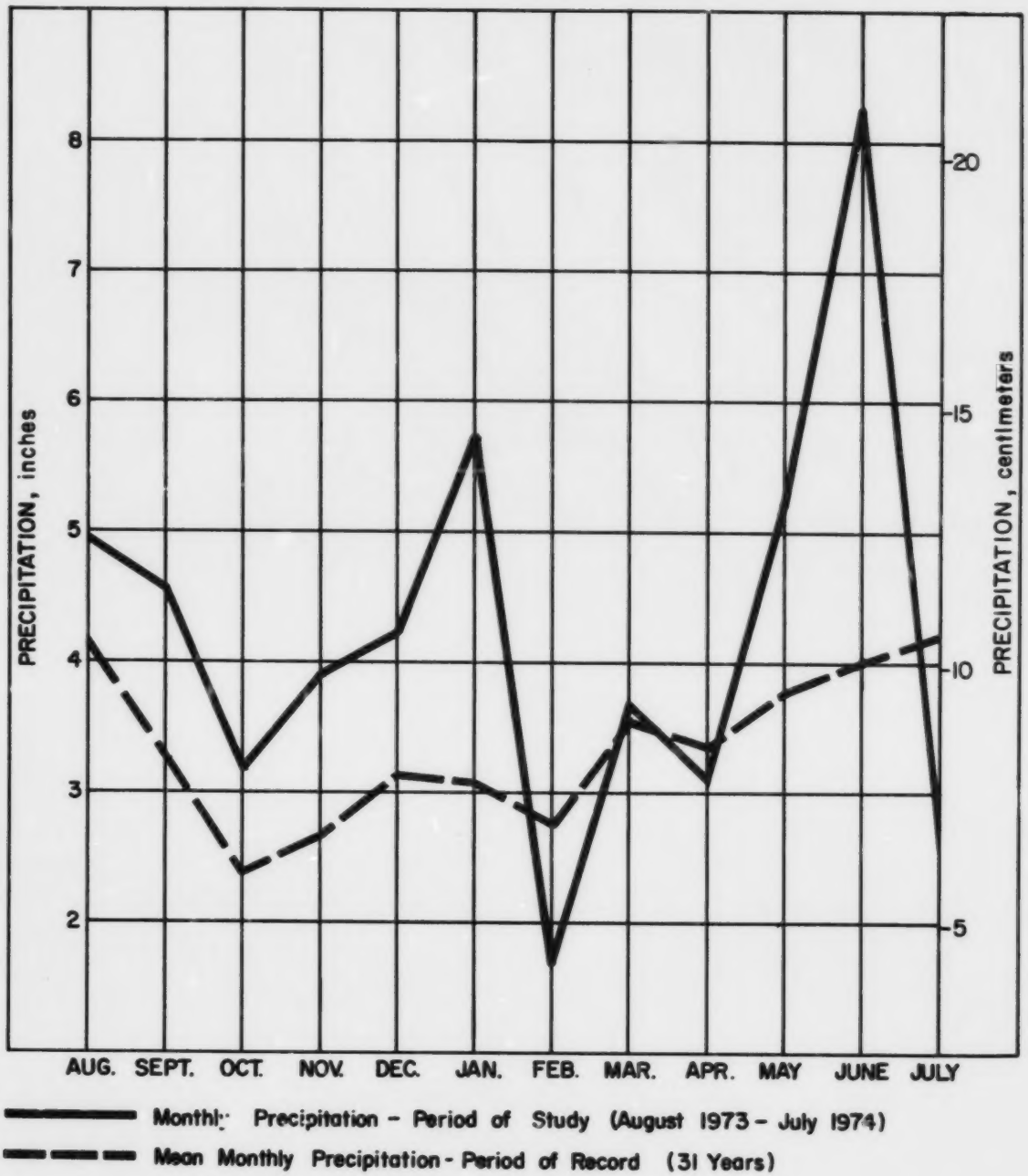


Figure 5. Monthly precipitation as recorded by the Clarksburg weather station.

mal precipitation is typical of the general area and is sufficient to replenish ground water storage and produce significant surface drainage. Examination of the precipitation and temperature charts show that for the study period monthly temperatures closely corresponded to thirty-one year normals; but the precipitation sharply deviated from thirty-one year normals. Total precipitation during the study period was 127.076 centimeters (51.03 inches) or approximately 27.534 centimeters (10.84 inches) above normal. Thus, the stream flows recorded during the study period are probably slightly greater than might be expected for a normal year.

SECTION VI

ABATEMENT TECHNIQUES

Five sites have been evaluated to determine the feasibility of demonstrating three abatement methods for elimination of pollution emanating from abandoned deep mines within the Elk Creek Watershed. Combinations of alkaline regrading, slurry trenching and mine roof collapse were considered for each of the project sites. Hydrogeologic conditions and the nature of coal mining within the watershed provide an ideal setting for demonstrating these abatement methods.

Each demonstration project site is characterized by polluted discharges from abandoned deep mine workings in the Pittsburgh coal seam. These discharges are partly the result of breached crop barriers during subsequent strip and auger mining. Large volumes of alkaline overburden provide for neutralization of deep mine discharges within alkaline rich spoil material. Proposed abatement methods will take advantage of these existing natural conditions to insure maximum neutralization is effected.

Slurry trench and alkaline regrading were proposed for all of the demonstration sites. The slurry trench is a narrow trench excavated in unconsolidated material with the vertical sides maintained by a very viscous water clay slurry (usually Bentonite) until fill (preferably mine spoil) can be placed. As the material dries an impermeable clay replaces the slurry. The completed slurry trench serves as an underground dam to inundate the unconsolidated material. Figure 6 illustrates a typical slurry trench.

Prior to construction of the slurry trench it will be necessary to regrade strip mine spoil. Spoil will be regraded by modified contour or terrace to produce a sufficient depth of material to construct a 4.6 to 7.6 meter (15 to 25 foot) deep slurry trench. Regrading will also serve to loosen the spoil material and enhance inter-spoil water flow. Following regrading the slurry trench is excavated through spoil to the Pittsburgh underclay. The underclay acts to retard water flow beneath the slurry trench. Exact placement and depth of the slurry trench is dependent on the dip of the underclay and the volume of available regradable spoil material. A typical alkaline regraded strip mine is illustrated in Figure 7.

An in-place slurry trench serves as a dam, causing a rise of mine

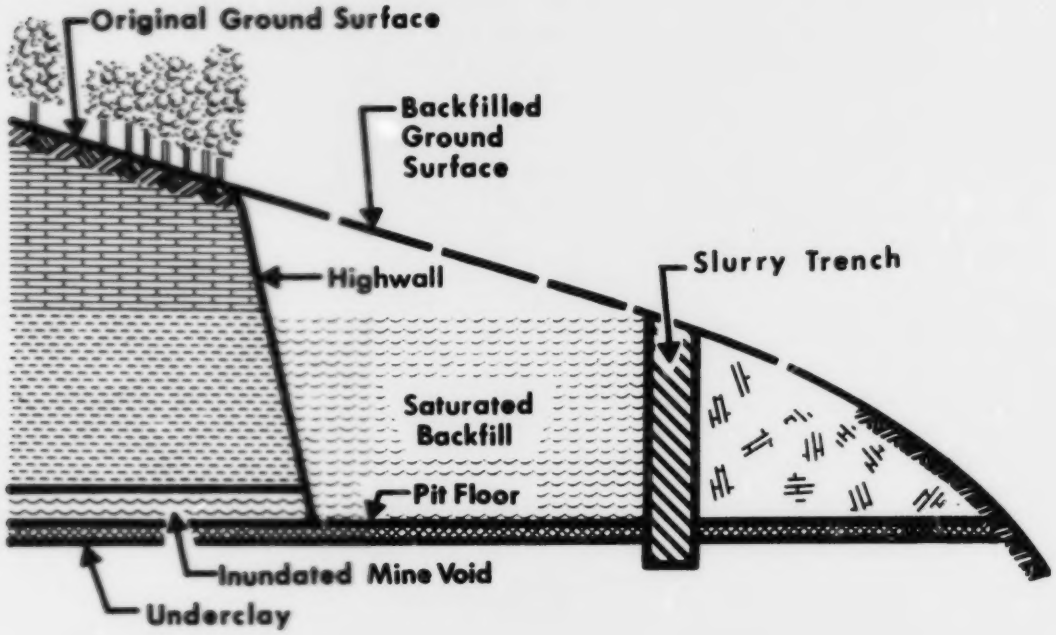


Figure 6. Typical slurry trench detail.

water level within spoil material prior to discharge at various points above the trench. This inundation exposes more inter-spoil limestone and claystone to contact with the acid water. Thus, neutralization is enhanced due to the increased contact, as well as a longer water residence time within the alkaline spoil. In addition to added neutralization, a reduction in acid drainage production will occur via deep mine inundation. Maximum extent of deep mine inundation is determined by elevation of the slurry trench and angle of rise of the coal in deep mine workings behind the highwall.

Mine roof collapse was considered in conjunction with alkaline regrading and slurry trench construction at Project Site #2. Since this site is an extremely large pollution source, the mine roof collapse will be performed to provide additional abatement of acid drainage. The concept involves collapsing the mine roof in the Pittsburgh coal workings

to retard water flow in the mines. This will achieve some inundation and provide access to portions of the alkaline claystone (mudstone) overlying the mine development. Acid production will be reduced and neutralization enhanced by mine roof collapse. This technique is not desirable for areas with acidic roof material, since additional acid forming material could be exposed to mine waters.

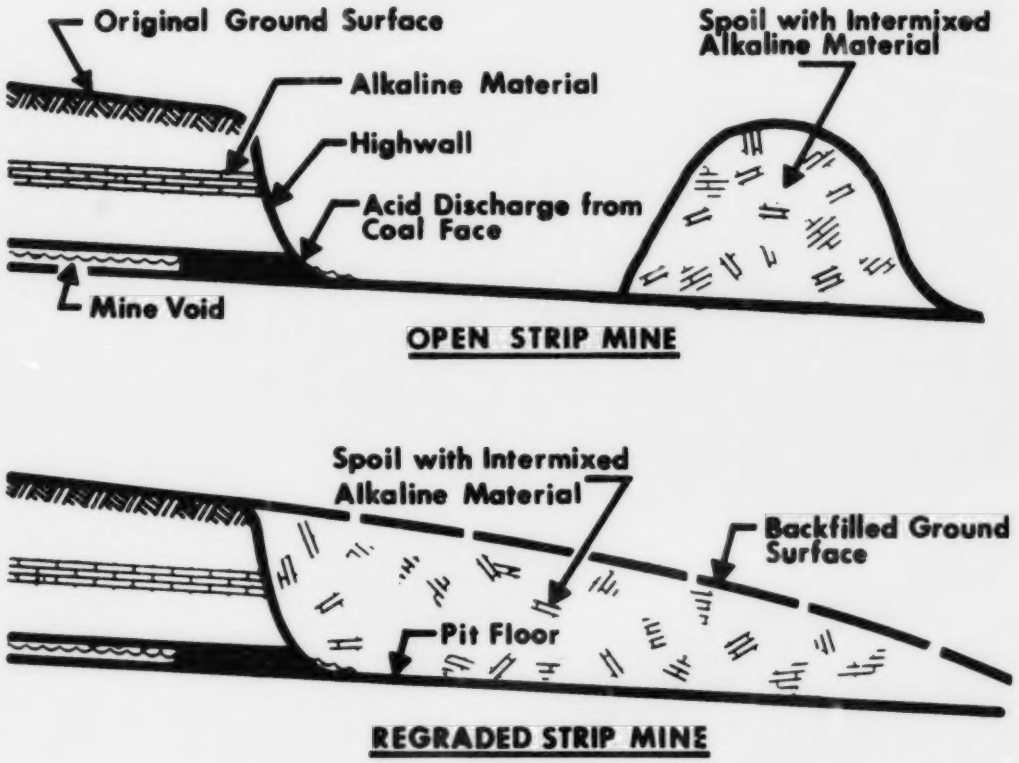


Figure 7. Typical alkaline regrading for stripped area.

SECTION VII

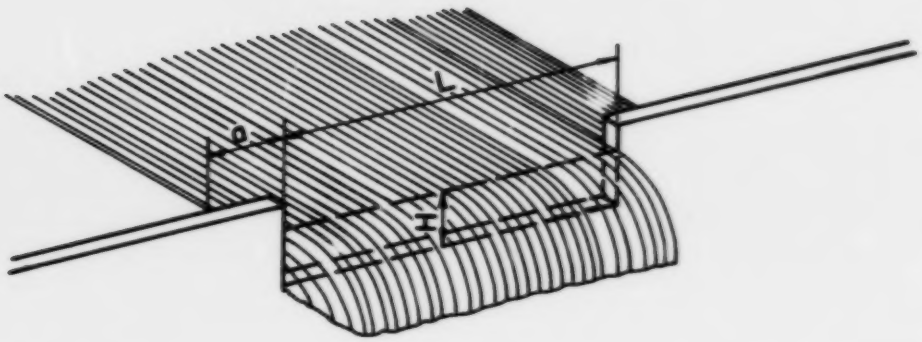
WATER QUALITY MONITORING

A water quality monitoring program was conducted as a part of this feasibility study to determine the extent of pollution emanating from individual project sites. Results of the monitoring program were used as an aid for evaluating project feasibility and determining expected project effectiveness toward eliminating water pollution. Water quality data recorded during this phase of the study will also be compared with data collected in Phase IV (Monitoring) following abatement construction (Phase III). This will provide a basis for determining initial project effectiveness.

The water quality monitoring program included installation of wooden V-notch and rectangular weirs to permit accurate flow measurements. Typical rectangular and V-notch weir diagrams are shown in Figures 8 and 9. The selection of wooden weirs was to eliminate many of the inherent problems associated with permanent concrete continuous monitoring stations. Periodic flooding and siltation problems necessitate regauging and cleaning of continuous monitoring equipment. In addition, wooden weirs are less expensive to install and provide required station mobility.

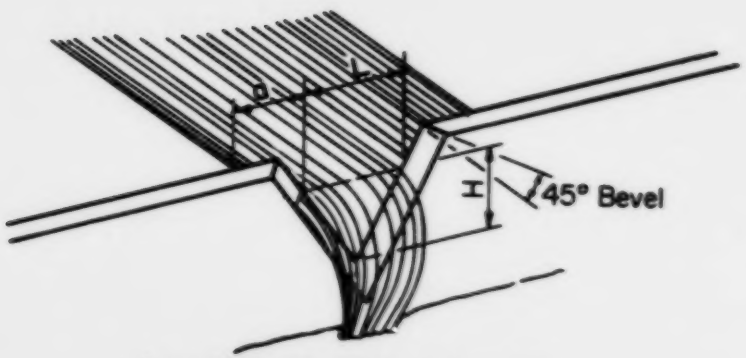
Present monitoring station locations may be antiquated due to relocated discharge points resulting from abatement construction. It will be possible to remove these antiquated weirs and install them on the particular diverted discharge. Although these wooden weirs did alleviate equipment gauging and cleaning, there is a problem with siltation occurring at several of the stations. However, the silt is easily removed with hand shovels.

A sampling round consisted of visiting each monitoring station once a month for the initial seven months and bi-monthly for the remaining months to record the flow and collect water samples. Where installation of weirs was not feasible, the flow was determined by field cross-sections and gurley meter recordings. At certain monitoring stations located on deep main streams, the downstream flows were calculated by adding the flow from the mine discharge to the flow recorded up stream from the discharge point. Since no additional flow augmentations occur between the two main stream stations, this method of determining flows provides comparable data for analyzing pollutant loadings from the acid discharges.



L= length of weir opening in feet
(should be 4 to 8 times H)
H= head on weir in feet (to be measured
at least 1.83 meters [6 feet] back
of weir opening)
a= should be at least 3H

Figure 8. Typical rectangular weir with end contractions



L= width of notch in ft. at H
distance above apex.
H= head of water above apex of notch in ft.
a= should not be less than 3/4 L

Figure 9. Typical right angle V-notch weir with end contractions.

A one pint water sample and a smaller field acidified sample were collected at each monitoring station. The pint samples taken during monthly sampling were than analyzed for: pH values; acidity - alkalinity; sulfates; and specific conductivity. The acidified samples were analyzed for iron. With the initiation of bi-monthly monitoring the following constituents are analyzed periodically: ferrous iron; magnesium; calcium; manganese; aluminum; suspended solids; and turbidity. Pollutant loadings (kg/day) were calculated from the concentrations and flows. All sampling data is averaged and tabulated in the Appendix.

SECTION VIII

PRE-DESIGN ENGINEERING

PROJECT SITE #1

Site #1 is located in the extreme northeast corner of the Elk Creek Watershed. Geology is typical for this region with both the Redstone and Pittsburgh Coals present. Since the Redstone and Pittsburgh seams average 1.5 to 2.7 meters (5 to 9 feet) thick, respectively, the area was subject to extensive underground mining in the past, and crop coals are now being extracted by surface mining techniques. However, crop coal has not been mined at the proposed demonstration site.

The abandoned Berryburg deep mine with extensive development in the Pittsburgh seam is the source of mine drainage pollution at this site. Most of this drainage emanates from three individual points. Two of these discharges occur along the Pittsburgh coal cropline where underground mine entries were driven through the crop coal, permitting exit of mine waters. These two flows are collectively monitored at Sample Station 1B (see Figure 10). A total average flow of 0.012 cu.m/sec. (0.42 cfs) represents a continuous augmentation from fresh surface runoff in addition to the deep mine discharges. Sample Station 1A (see Figure 10) is the monitoring point for a third discharge that emanates from the Berryburg Tunnel. This railroad tunnel was excavated through abandoned deep mine workings, intercepting mine waters and providing a point for discharge. An average flow of 0.736 x 10^{-2} cu.m/sec. (0.260 cfs) from the Berryburg Tunnel joins the two other discharges prior to a confluence with Stewart Run. Total average pollutant loadings monitored at Sample Stations 1A and 1B are 477 kg/day (985 lbs/day) acidity, 69 kg/day (152 lbs/day) total iron, and 1577 kg/day (3477 lbs/day) sulfates (see the Appendix). Mine drainage pollution emanating from Project Site #1 is a major reason for the present degraded condition of Stewart Run. In addition, pollutants in Stewart Run are discharged to Elk Creek, which at present has marginal water quality capable of supporting aquatic life. Any efforts to minimize pollution at Project Site #1 will help insure a continued upgrading of water quality in Elk Creek.

This particular source of mine drainage was evaluated during the Feasibility Study to determine both feasibility and desirability of demonstrating alkaline regrading and slurry trench construction as mine drainage abatement techniques. All construction efforts are dependent on the

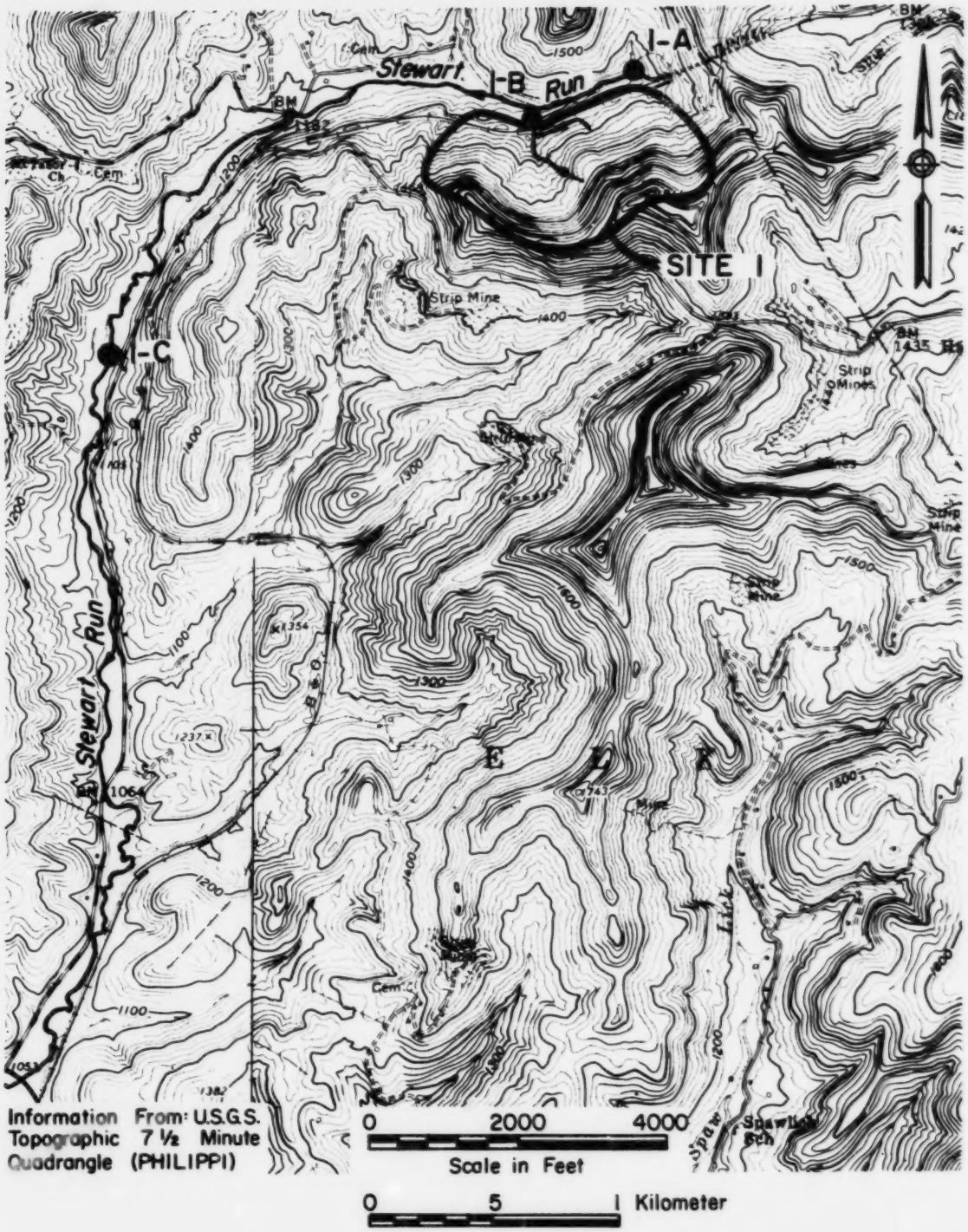


Figure 10. Sample station map for demonstration project site no. 1.

scheduled strip mining of crop coal to provide alkaline spoil for regrading and trench excavation. Following completion of surface mining, the area should be remapped, and exploratory backhoe excavation should be conducted. This backhoe excavation will provide information concerning depths of strip mine spoil. Figure 11 shows a major portion of the proposed construction area.

Figure 11. Photograph of demonstration project site no. 1.

Assuming surface mining will be completed soon enough to allow mapping for detailed construction design, the total estimated cost for aerial photography, mapping, regrading, revegetation and constructing of 610 meters (2,000 L.F.) of slurry trench is $189,700. Profiles and sections were not prepared during the Feasibility Study since existing conditions will be altered by strip mining operations.

Implementation of the proposed demonstration project is deemed tech-

nically and economically feasible. Abatement construction should effectively eliminate most of the pollution recorded at Sample Station 1B. In addition, surface mining is expected to divert flow from the Berryburg Tunnel and include these waters within proposed abatement construction. Thus, approximately 477 kg/day (985 lbs/day) of acid will be neutralized following project construction. This reduction in acidity will eliminate acidity loadings recorded at Sample Station 1C (see Figure 10) and result in alkaline water quality for the upper reaches of Stewart Run. The estimated cost effectiveness to accrue these benefits is $398 per kg/day ($180 per lb/day) acid abated. Quantities of work were determined through detailed field investigations and estimates of maximum reworking required for regraded spoil material. Since the area will be reclaimed following mining, project grading and revegetation should be minimal.

Estimated Construction Costs Site #1

Grading = 22,938 cu m @ $0.65/cu m = $ 15,000
(30,000 cu yd @ $0.50/cu yd)

Slurry Wall = 0.6 m wide x 6.10 m deep x 609.60 m
(2 ft wide x 20 ft deep x 2,000 L.F.)

3,716 profile sq m @$43.06/sq m = $160,000
(40,000 profile sq ft @$4.00/sq ft)

Revegetation = 2.43 ha @ $1,235/ha = $ 3,000
(6 ac @ $500/ac)

Contingency = 5% = $ 8,900

Aerial Photography and Mapping = lump sum = $ 2,800

Total = $189,700

PROJECT SITE #2

This project site is also located in the northeastern portion of the Elk Creek Watershed, approximately 4.8 kilometers (3 miles) west of Site #1. The generalized stratigraphic column (Figure 3) was recorded at Site #2 and thus, reflects specific local stratigraphy, as well as general stratigraphy for the watershed. Local topography is illustrated by Figures 12 and 13.

A steep hillside delineated as the project site was subject to underground coal mining and subsequent contour strip mining. Apparent breaches of the coal crop barrier produced numerous acid discharges

Figure 12. Photograph of demonstration project site no. 2.

from underground workings. In addition to past mining, strip mining of remaining crop coal was initiated while this Feasibility Study was being conducted. As a result of active mining, flow monitored at Sample Station 2D was diverted to Sample Station 2D' (See Figure 14).

Project Site #2 is the largest single pollution source among the five potential demonstration project sites. Combined major pollutant loadings recorded at Sample Stations 2B and 2D' are: 648 kg/day (1429 lbs/day) acidity, 153 kg/day (337 lbs/day) total iron, and 1362 kg/day (3003 lbs/day) sulfates. A majority of these contaminants will be eliminated as a result of abatement construction. Results of analyses

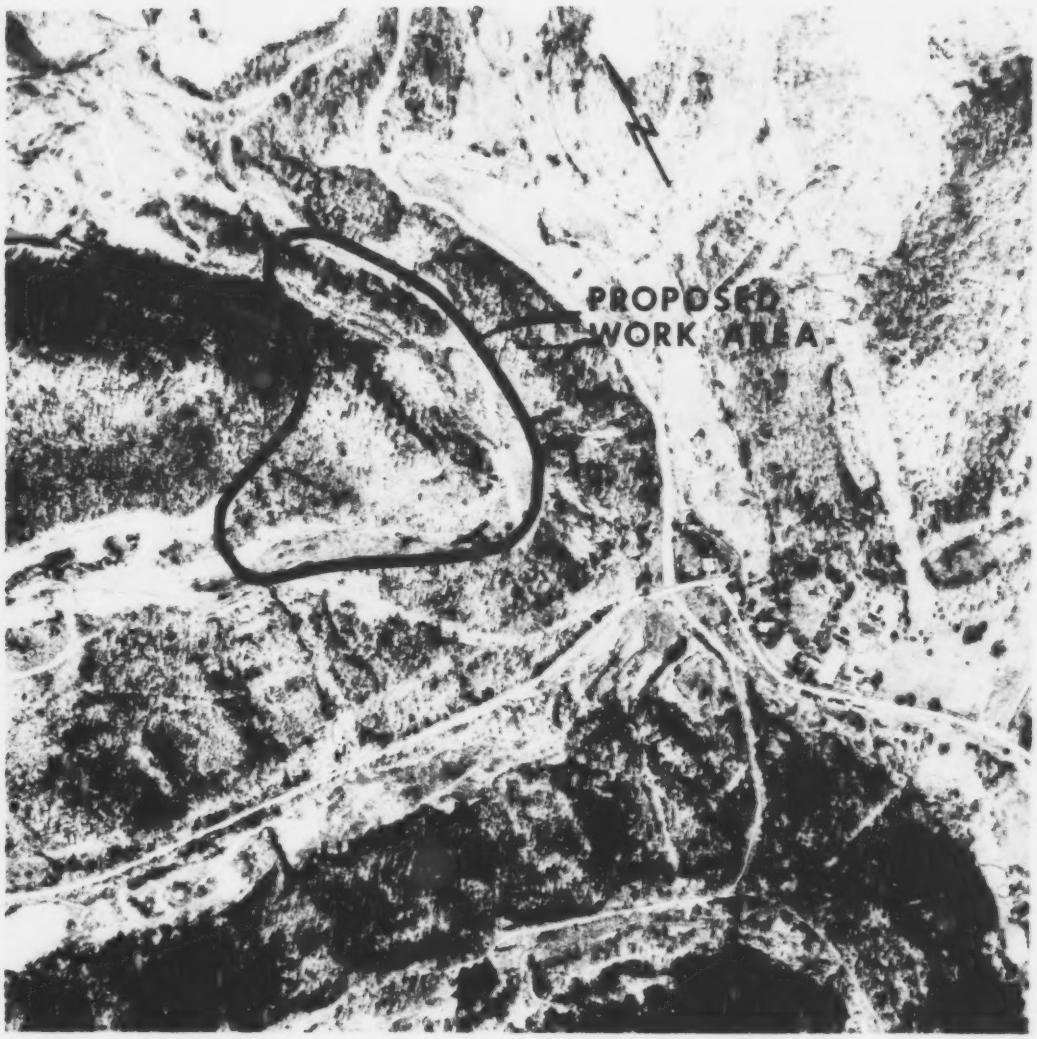


Figure 13. Aerial view of demonstration project site no. 2.

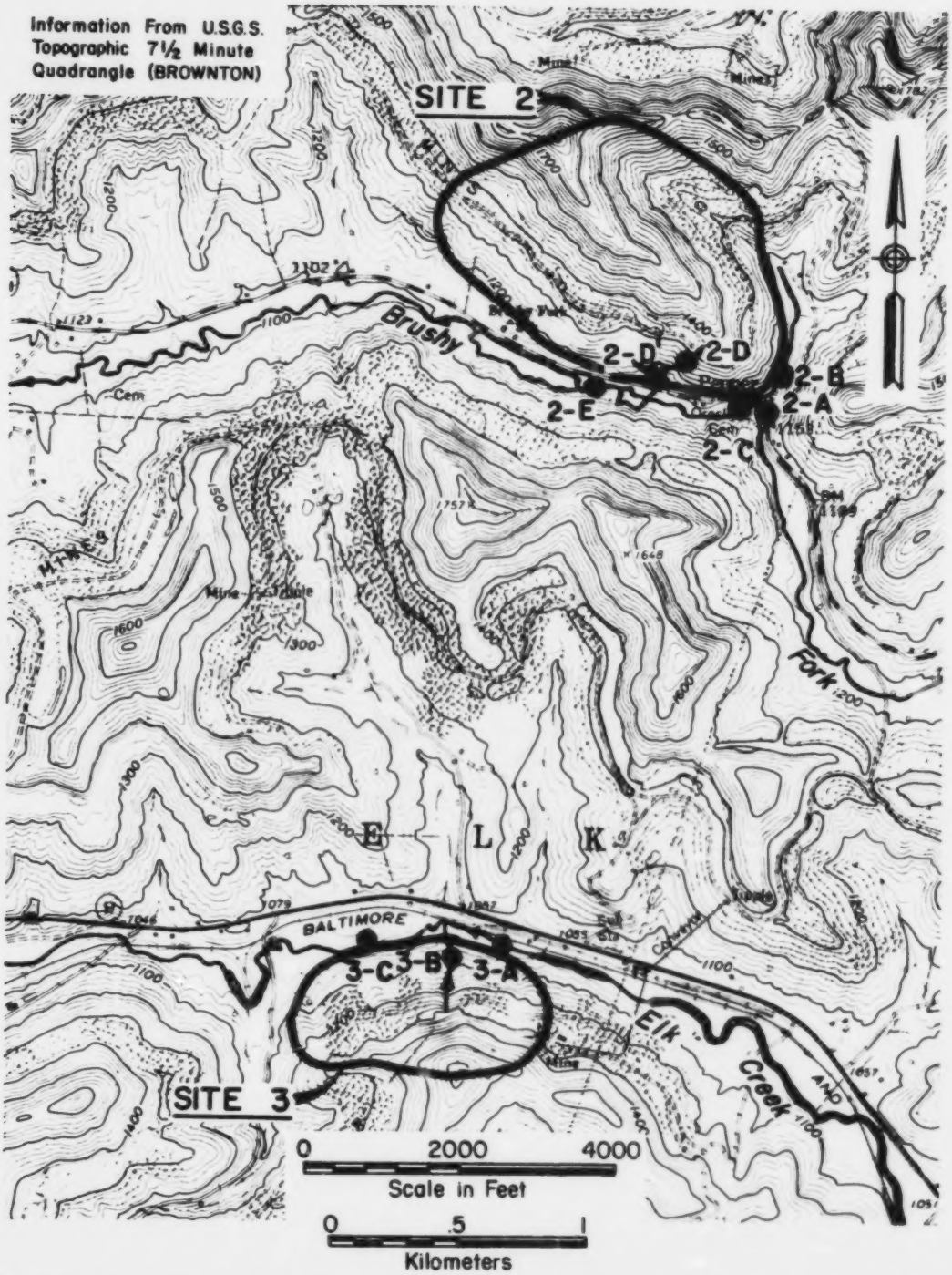


Figure 14. Sample station map for demonstration project sites no. 2 & 3.

of thirteen chemical parameters are listed in the Appendix. Post construction monitoring will provide data to evaluate changes in concentrations and loadings of each constituent. Expected results are a reduction in acidity, iron, manganese and aluminum with corresponding increases in alkalinity (therefore pH), magnesium, calcium, suspended solids, and turbidity. Other constituents should not be significantly affected by abatement measures.

Acid flows from this project site discharge to Brushy Fork. Monitoring data from Sample Station 2A show that Brushy Fork has a net alkalinity prior to receiving mine drainage from Project Site #2. Severe pollution from this site results in an average net acid loading of approximately 500 kg/day (1102 lbs/day) monitored at Sample Station 2E immediately downstream from the last acid discharge. Brushy Fork flows northwest until its confluence with Elk Creek. Thus, pollution from Site #2 eventually contributes to further degradation of Elk Creek, and project abatement efforts will improve both Brushy Fork and Elk Creek.

Abatement construction proposed for Project Site #2 includes mine roof collapse in conjunction with alkaline regrading and slurry trench construction. Each of these abatement measures is predicated on the assumption that sufficient quantities of alkaline overburden material are available for dispersion within spoil material to effect neutralization. Overburden samples were collected and analyzed to determine neutralization potential. Since active mining at Project Site #2 exposed unweathered overburden rock units, all samples were collected at this site. This also provides excellent correlation with the stratigraphic column. Sample locations and calcium carbonate equivalences are listed on the following Table. With the exception of a shale unit located approximately 4.3 meters (14 feet) above the Pittsburgh Coal, all materials tested have neutralization potential. As expected, the mudstone (claystone) and limestone units have the greatest neutralization capability. In addition, these units are extremely friable, which will permit fragmentation and expose maximum reactive surface. These neutralization potentials were used to estimate the effective life of proposed abatement at Project Sites #3, 4 and 5. Estimates are not provided for Sites #1 and 2 since specific backfill conditions were not known at the time of this report.

The required amounts of regrading and slurry trench were estimated for Site #2 by considering existing conditions and surface mining plans. It is estimated that the total construction cost to demonstrate mine

SOIL SAMPLE ANALYSIS TABLE

(All samples were taken at Demonstration Project Site No. 2)

SAMPLE NUMBER	SAMPLE LOCATION	$CaCO_3$ Equiv. (M-tons / 1000 M-tons) Tons/1000 Tons
A_1	Located approximately 0.9m(3ft.) below Pittsburgh Rider, in alkaline mudstone and limestone.	329.47
A_2	Located approximately 0.5m(1.5ft) above Pittsburgh Rider, in medium-fine grained sandstone.	25.02
A_3	Located approximately 0.9m(3ft.) below Redstone, in interbedded shale and siltstone.	19.99
A_4	Located approximately 3.7m (12ft.) above Pittsburgh, in talus slope from existing highwall.	23.73
A_5	Located approximately 4.3m (14 ft.) above Pittsburgh, in friable shale.	-2.06
B_1	Located stratigraphically in same general area as Sample A_1.	358.43
B_2	Located stratigraphically in same general area as Sample A_1.	299.14
B_3	Located in talus slope from existing highwall.	38.44

roof collapse, alkaline regrading and slurry trench construction will be $173,000. This cost includes aerial photography and remapping because of alterations produced during mining. Although remapping of the project area is necessary; drainage, geologic and mining parameters are ideal for demonstration of proposed abatement techniques. Therefore, abatement demonstration for Project Site #2 is found to be technologically feasible. The cost effectiveness to demonstrate abatement of mine drainage at this site is $318 per kg/day (144 per lb/day) acid abated. Quantities of work were estimated with considerations similar to those employed for Site #1.

Estimated Construction Costs Site #2

Grading =	45,876 cu m @ $0.65/cu m (60,000 cu yd @ $0.50/cu yd)	= $ 30,000
Slurry Wall =	0.6 m wide x 6.10 m deep x 457.20 m (2 ft. wide x 20 ft. deep x 1500 LF)	
	2,787 profile sq m @ $43.06/sq m (30,000 profile sq ft @ $4.00/sq ft)	= $120,000
Revegetation =	2.03 ha @ $1235/ha (5 ac @ $500/ac)	= $ 2,500
Mine Roof Collapse =	lump sum	= $ 10,000
Contingency =	5%	= $ 8,100
Aerial Photography and Mapping =	lump sum	= $ 2,400
	Total	= $173,000

PROJECT SITE #3

Located approximately 4.8 kilometers (3 miles) south of Site #2, Project Site #3 is geologically similar to each of the demonstration sites previously described. Both the Pittsburgh and Redstone Coals are present and were in the past subject to underground or strip mining. An average of 2.1 meters (7 feet) of Pittsburgh coal was mined by underground methods, followed by strip mining along the cropline. These stripping operations extracted roughly 1.2 meters (4 feet) of Redstone in addition to Pittsburgh Coal. Present topography reflects past mining efforts with a partially exposed highwall

extending above 6.1 to 12.2 meters (20 to 40 feet) of terraced spoil material (see Figure 15). This spoil material blankets the Pittsburgh underclay which serves as an impervious barrier to mine drainage discharged through breached deep mine entries. Much of the deep mine drainage is transmitted via a local syncline and exists along the outer spoil slope. Samples are collected and flows recorded for this discharge at Sample Station 3B (see Figure 14). The aerial view in Figure 16 shows several discharge points.

Figure 15. Photograph of demonstration project site no. 3.

Figure 16. Aerial view of demonstration project site no. 3.

Sampling data presented in the Appendix shows that an average of 26 kg/day (57 lbs/day) acid, 11 kg/day (24 lbs/day) total iron, and 251 kg/day (553 lbs/day) sulfates are discharged directly into Elk Creek. In addition several smaller seeps contribute pollutant loadings to Elk Creek. These individual seeps do not have enough flow to facilitate accurate measurement. However, it is reasonable to assume such flows do have a quality similar to drainage monitored at Sample Station 3B. Since Elk Creek has a much larger flow, the combined acid seeps have little affect on water quality in Elk Creek.

However, sufficient pollution is emanating from Site #3 to provide a control data base for demonstration of mine drainage abatement techniques. With an estimated total acid loading of 52 kg/day (114 lbs/day), calculations indicate that with only a twenty-five percent availability of the neutralizing potential within proposed construction limits, acid loadings would be abated for more than 600 years. These estimates and estimates for Site #4 were developed through the following reasoning:

- Cross sections and profiles were used to determine the volume of available spoil material.
- The alkalinities determined for soil analyses at Site #2 and the average thicknesses of individual stratigraphic units were employed to proportion overburden material and alkalinity for the entire quantity of spoil.
- A twenty-five percent spoil availability is presented for illustrative purposes only and is not intended to represent actual conditions which would require detailed field and laboratory testing.
- It was assumed that one pound of alkalinity as indicated by soil tests could neutralize an equivalent one pound of acid being discharged from the abandoned deep mine.

Proposed abatement demonstration techniques consist of alkaline regrading and slurry trench construction. The slurry trench location is shown in Figure 17. Cross sections in Figure 18 illustrate spoil material before and after completion of alkaline regrading. Figure 19 shows a profile of the proposed slurry trench. This trench is designed to force discharge at the location of Sample Station 3B. Thus, flows can be monitored without relocation of the existing V-notch weir. The slurry trench height at this designed discharge point fixes a maximum water head of 6.1 meters (20 feet) in spoil material and deep mine workings. The maximum desired head was established by considering underclay elevations at several mine entries shown on

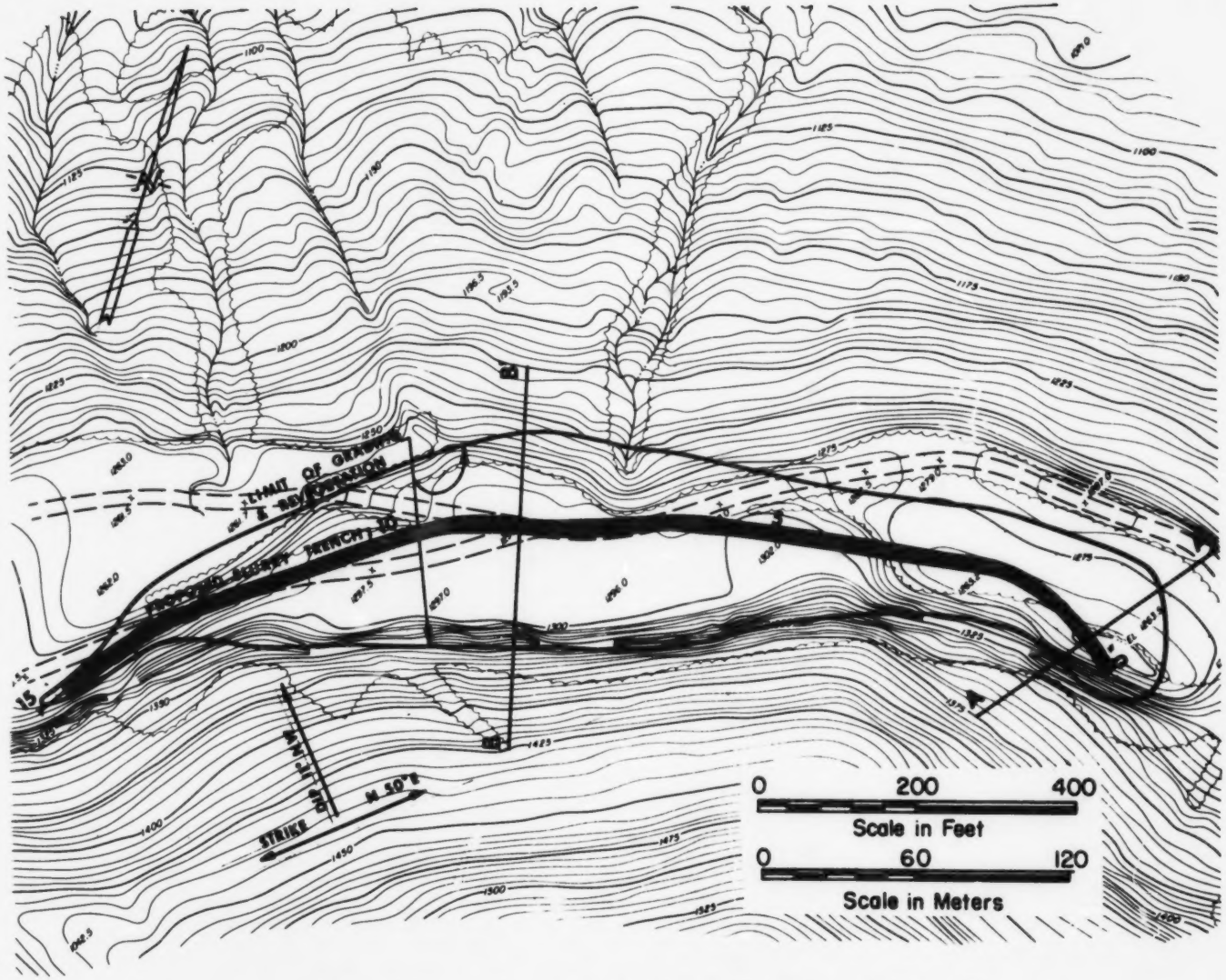


Figure 17. Plan of demonstration project site no. 3.

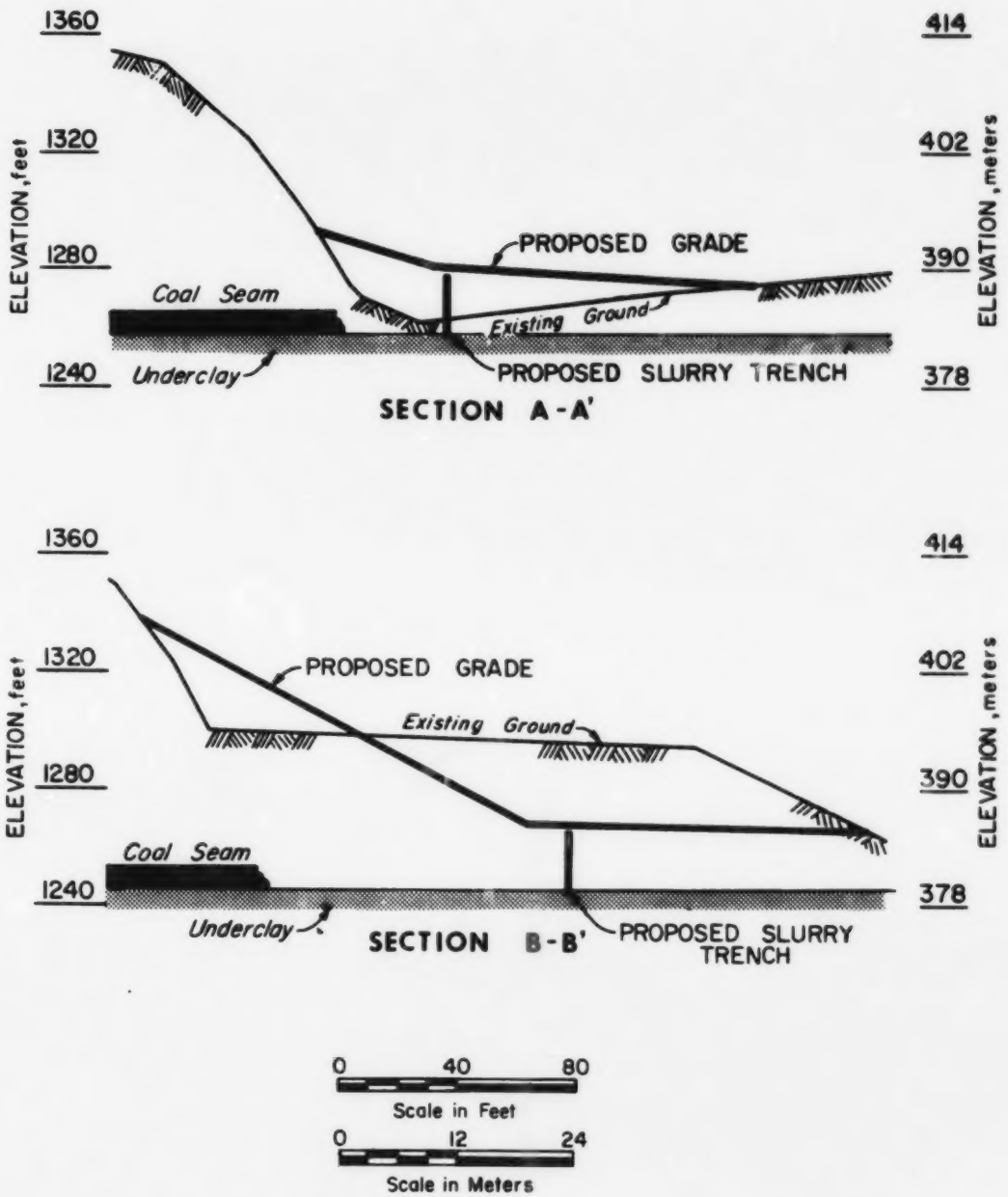


Figure 18. Cross sections of demonstration project site no. 3.

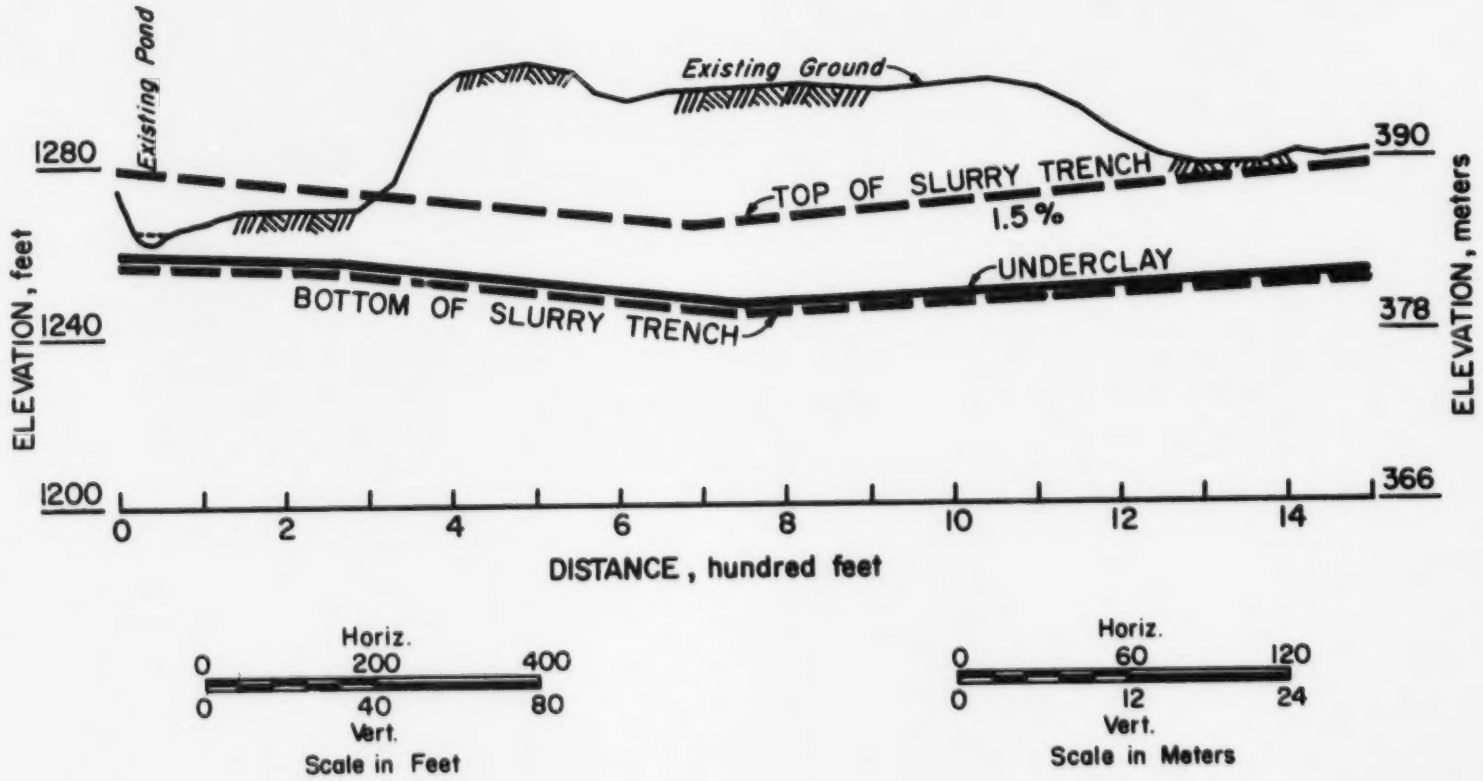


Figure 19. Profile of demonstration project site no. 3.

mine mapping. A final mine pool elevation was determined to avoid overflow through these abandoned mine entries.

Approximately 100 percent effectiveness is expected for eliminating pollution from Project Site #3. The total estimated construction cost is $171,300 for regrading, slurry trench construction and revegetation. Cost effectiveness will be $6,590 per kg/day ($2,989 per lb/day) acid abated. Considering abatement of mine drainage discharges that were not recorded, a lower cost effectiveness will be achieved. Despite a high cost effectiveness, Project Site #3 is a feasible location for demonstrating both alkaline regrading and slurry trench mine drainage abatement techniques. All main stream water quality improvement resulting from abatement projects is a supplementary benefit derived during demonstration of abatement techniques.

Estimated Construction Costs Site #3

Grading = 44,347 cu m @ $0.65/cu m (58,000 cu yd @ $0.50/cu yd)	= $ 29,000
Slurry Wall = 0.6 m wide x 6.71 m deep x 457.20 m (2 ft. wide x 22 ft. deep x 1500 LF)	
3,047 profile sq m @ $43.06/sq m (32,800 profile sq ft.@ $4.00/sq ft.)	= $131,200
Revegetation = 2.43 ha @ $1235/ha (6 ac @ $500/ac)	= $ 3,000
Contingency = 5%	= $ 8,100
Total	= $171,300

PROJECT SITE #4

Site #4 is located in the northwest corner of the Elk Creek Watershed. Topography is characteristic of this region with steep sloping hillsides dissected by valleys and streams. Valleys are usually barren of coal resulting from post-depositional erosion or a void in original deposition. Geologic conditions resemble other project sites with one major exception. The Redstone coal seam is not present, and instead is represented by a dark shale. 2.1 meters (7 feet) of Pittsburgh Coal is present and has been mined by both underground and surface mining methods. However, this area has not been subject to recent

secondary stripping. Lack of renewed mining efforts may be attributed to small remaining crop coal barriers and an absence of mineable Redstone Coal.

This specific project site is a hill extending from a more persistent ridge and surrounded on three sides by valleys (see Figures 20 and 21). Strip mining around the hill perimeter has breached underground workings providing exit points for deep mine waters. Spoil from surface mining was cast downslope and backfilling was not conducted. Thus, breached mine workings are exposed as shown in Figure 22, and Figure 23 shows an abandoned stripping shovel.

Figure 20. Photograph of demonstration project site no. 4.

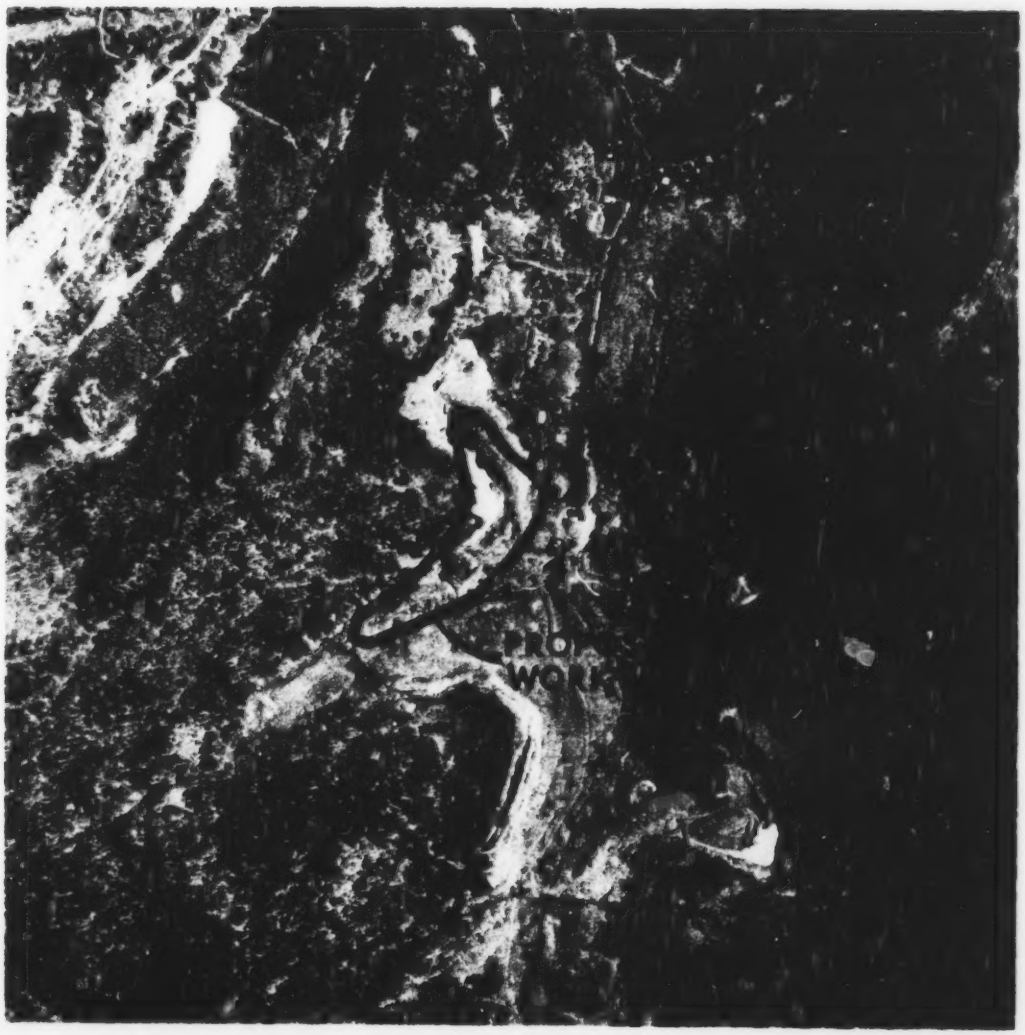


Figure 21. Aerial view of demonstration project site no. 4.

In addition to drainage from breached openings, an overflow is occuring at an abandoned drift deep mine entry. Combined mine drainage flows are monitored at Sample Station 4B (see Figure 24). Major pollutant loadings discharged from Project Site #4 averaged 139 kg/day (306 lbs/day) acidity, 38 kg/day (83 lbs/day) total iron and 550 kg/day (1213 lbs/day) sulfates during the Feasibility Study. Analyses of these and other chemical constituents are listed in the Appendix, along with calculated loadings. An average acid flow of 0.386×10^{-2} cu m/sec (0.136 cfs) directly augments the headwaters of Nutter Run. Water quality in Nutter Run maintains a net alkalinity following confluence with Site #4 discharge. However, net alkalinity is reduced by acid

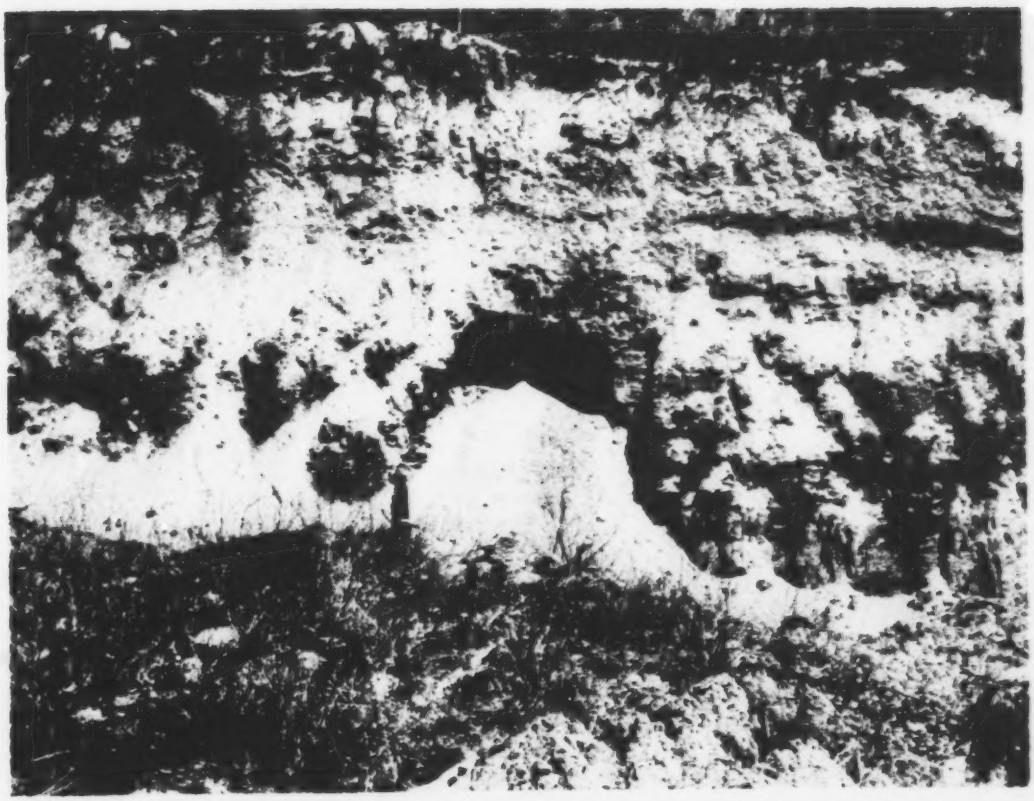


Figure 22. Breached deep mine entry at demonstration project site no. 4.

loadings. Nutter Run eventually joins Elk Creek at the towns of Nutter Fort and Stonewood. Contaminants in Nutter Run have little effect on quality of the large volumes of water in Elk Creek. Data recorded at Sample Station Composite indicates that mine drainage pollutants have been diluted by large volumes of good quality waters.

Thus, abatement demonstration measures recommended for Project Site #4 will be of minimal benefit to Elk Creek. Alkaline regrading and slurry trench construction are proposed for demonstration at this particular location. Figure 25 shows the planned slurry trench position along existing highwall limits. Trench limits are designed to encompass all acid discharges. Abatement construction is hindered by a lack of available spoil for regrading. This is illustrated by cross-

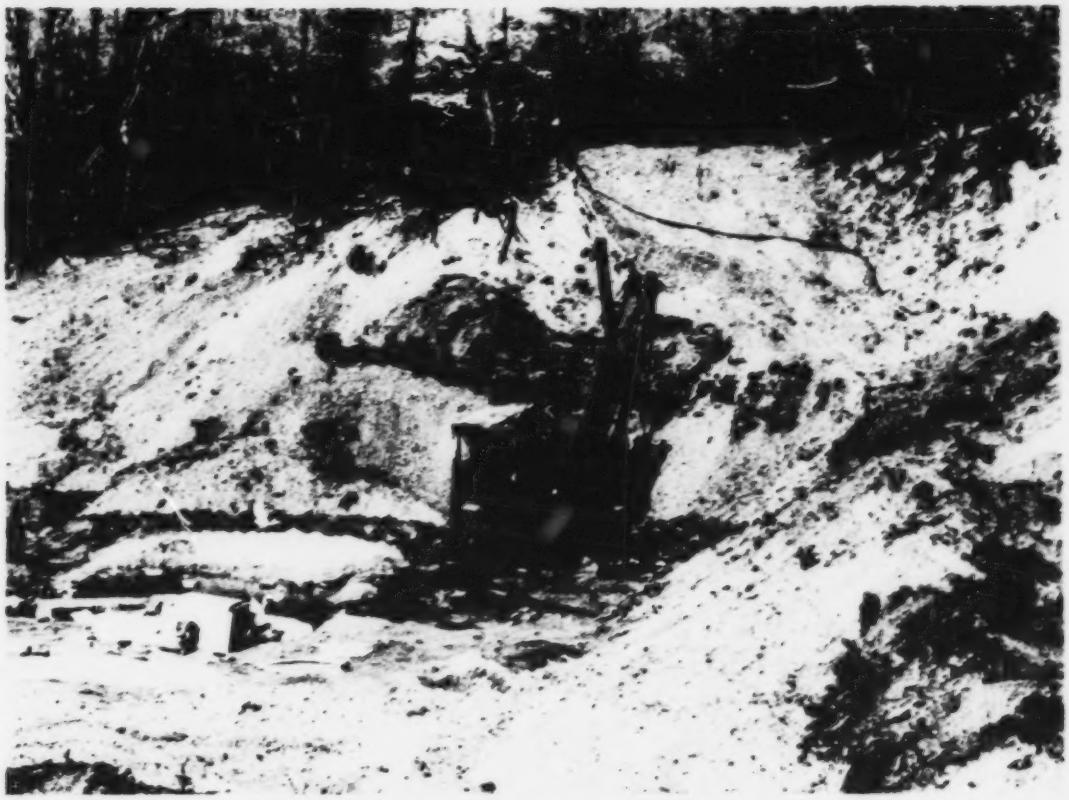


Figure 23. Abandoned stripping shovel at demonstration project site no. 4.

Figure 24. Sample station map for demonstration project site no. 4.

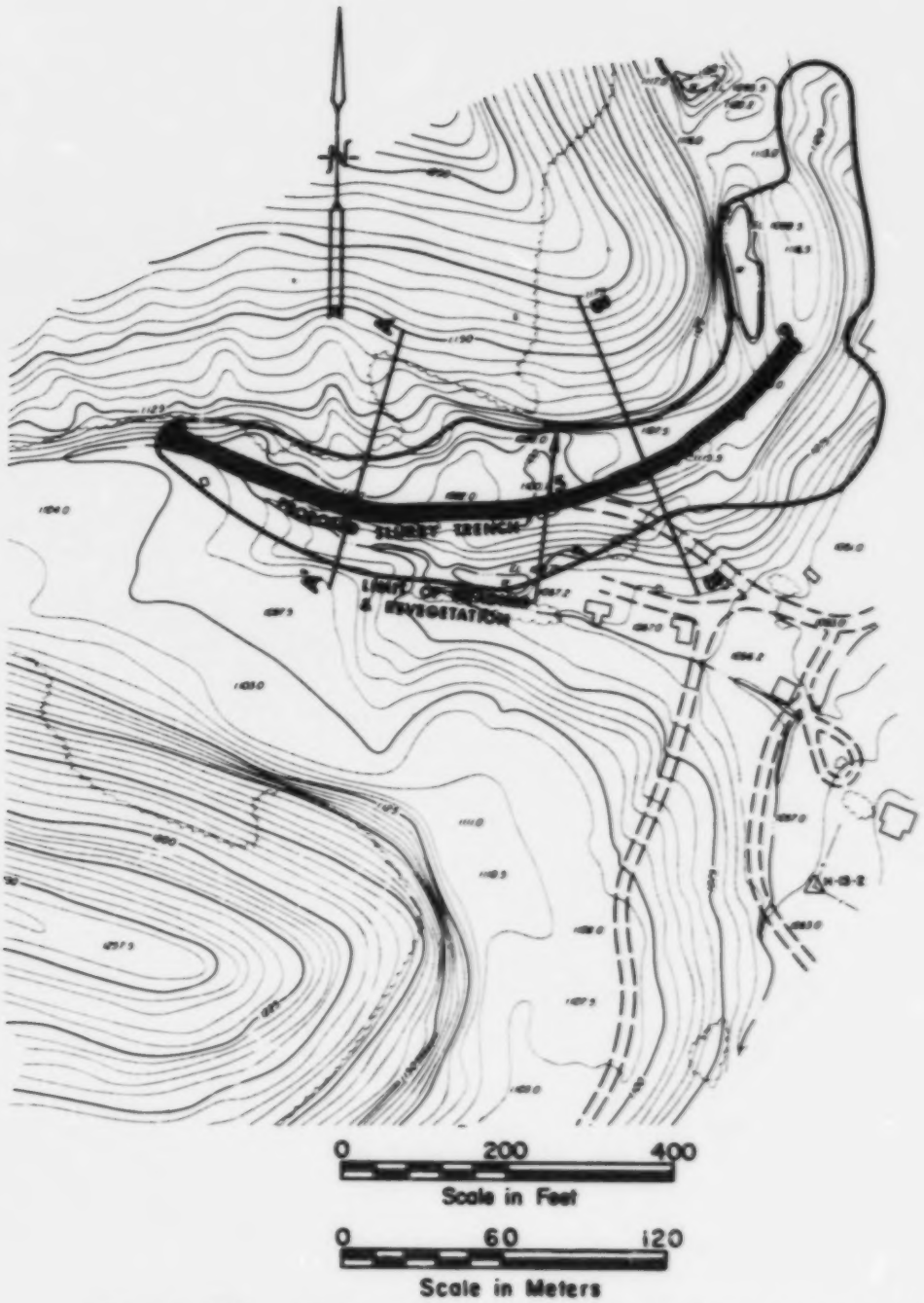


Figure 25. Plan of demonstration project site no. 4.

sections in Figure 26. Material will be pushed from the spoil slopes, graded against the highwall and compacted to facilitate trench construction. Also, the slurry trench is designed to allow a 3.0 meter (10 foot) maximum water head behind construction (see Figure 27). This maximum head was determined by considering deep mine development and the dip of the Pittsburgh Coal. Greater than 3.0 meters (10 feet) of head would force mine waters out of the hillside opposite construction.

Even though alkaline regrading and slurry trench construction are restricted, sufficient alkalinity is available to successfully demonstrate these abatement techniques. It is estimated that with total availability of alkaline material, acid will be neutralized for 200 years. If only 25 percent availability is assumed for illustrative purposes, acid reduction could continue for at least 50 years. Effectiveness is expected to approach 100 percent for reduction of existing acid loadings, and iron loadings will be significantly lowered as a result of oxidation processes. A total estimated construction cost of $62,100 to demonstrate proposed abatement techniques will afford a cost effectiveness of $450 per kg/day ($204 per lb/day) acid abated. All factors, including a poor quality discharge, no mining projected for the future, and sufficient amounts of available alkalinity are ideal for demonstration of proposed abatement techniques. In addition to water pollution related benefits accrued following construction, the existing highwall at Site #4 will be eliminated, thus providing aesthetic benefits.

Estimated Construction Costs Site #4

Grading = 13,304 cu m @ $0.65/cu m (17,400 cu yd @ $0.50/cu yd)	= $ 8,700
Slurry Wall = 0.6 m wide x 4.27 m deep x 3688.08 m (2 ft. wide x 14 ft. deep x 860 LF)	
1,124 profile sq m @ $43.06/sq m (12,100 profile sq ft. @ $4.00/sq ft.)	= $48,400
Revegetation = 1.62 ha @ $1235/ha (4 ac @ $500/ac)	= $ 2,000
Contingency = 5%	= $ 3,000
Total	= $62,100

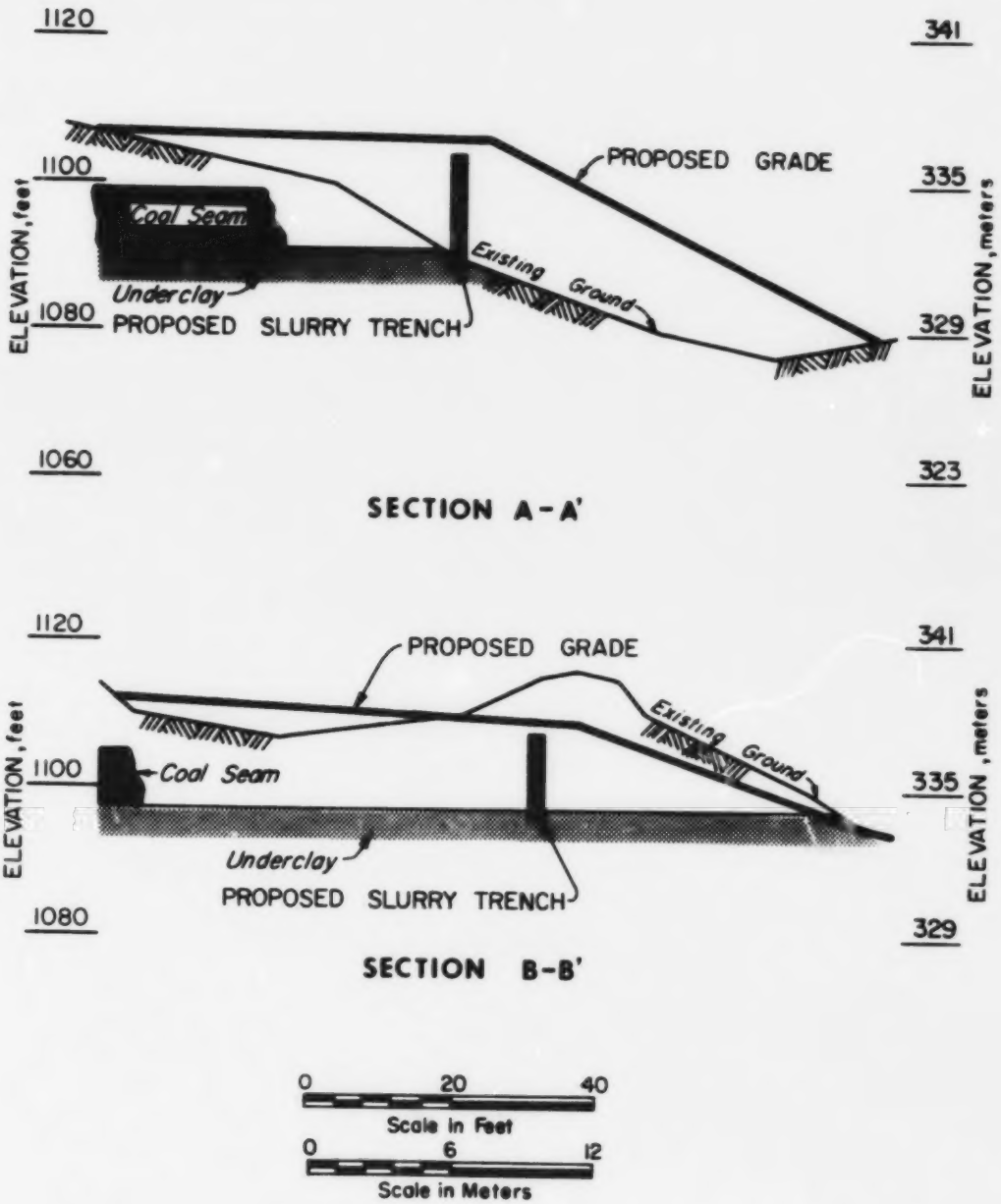


Figure 26. Cross sections of demonstration project site no. 4.

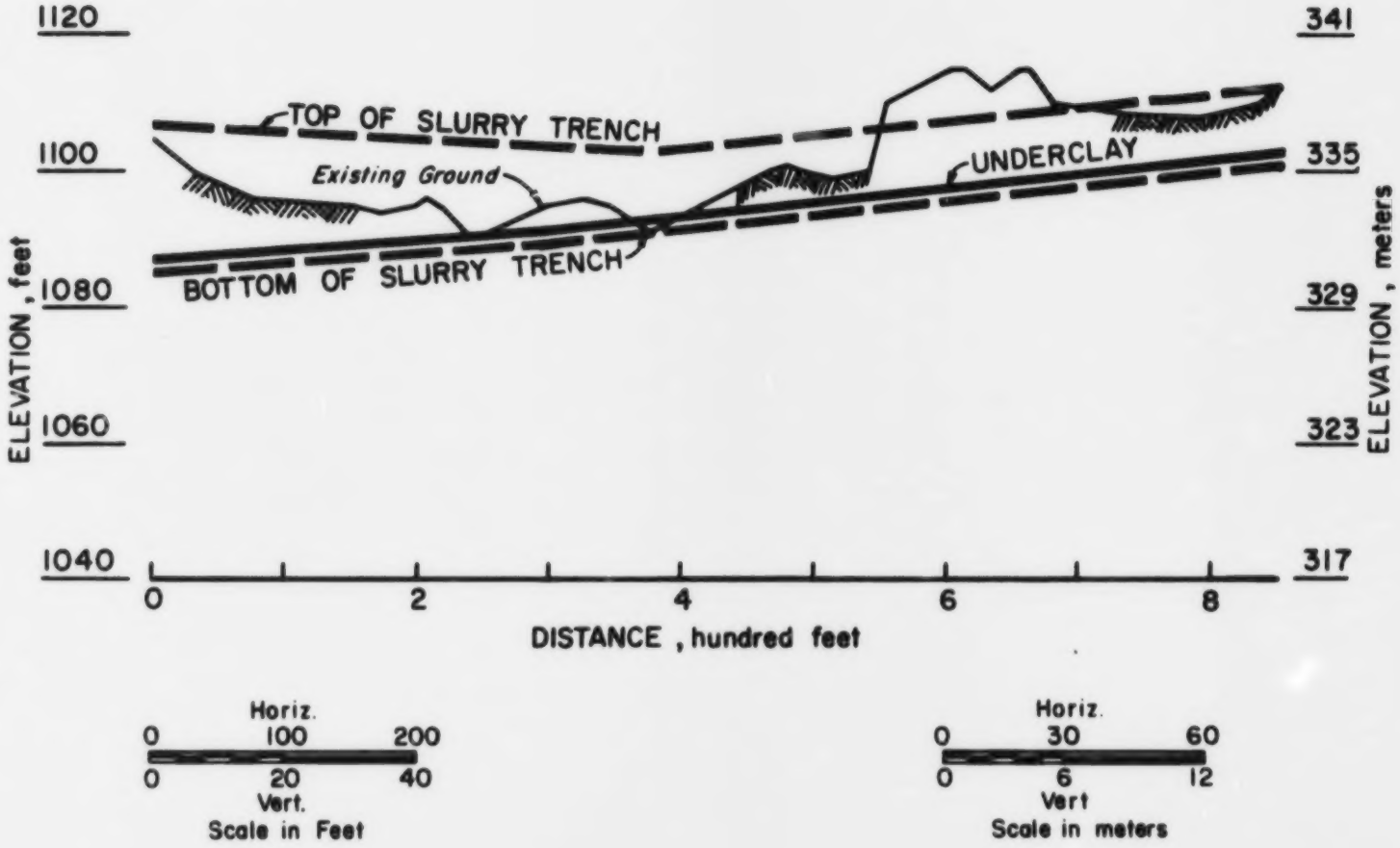


Figure 27. Profile of demonstration project site no. 4.

PROJECT SITE #5

This demonstration project site is located in the south central portion of the Elk Creek Watershed. Topography is again typical, consisting of steep sloping hills dissected by valleys and streams. These hills are stratigraphically composed of geologic rock units similar to those represented in the generalized stratigraphic column. Abandoned highwall exposures show that mudstone and limestone units are present to provide alkalinity in existing spoil material. Both the Pittsburgh and Redstone Coals are persistent throughout this portion of the Elk Creek Watershed. Thus, extensive mining has occurred in the past and active mining is presently being conducted in the vicinity of Project Site #5.

The actual project site is the point of a hill or ridge which is bordered on three sides by stream valleys (see Figures 28 and 29). Much of the Pittsburgh Coal seam has been extracted via underground mining, and subsequent contour stripping has removed deep mine crop barriers in the Pittsburgh and any overlying Redstone crop coal. Auger mining of Redstone Coal was a common practice in this area, but augering was not employed at Site #5. As a result of surface mining, a spoil bench that ranges from 6.1 to 12.2 meters (20 to 40 feet) deep exists at this locale, providing good conditions for excavating a slurry trench.

Mine drainage occurs as wicespread seeps along the southern portion of this undermined hillside. These seeps are collectively monitored at Sample Station 5B (see Figure 30). Chemical analyses of samples collected from this discharge during initial sampling rounds indicate that the flow was acid (see the Appendix). However, all analyses recorded following the third sampling round show net alkalinity, with a subsequent decrease of acidity concentrations to zero. Field investigation failed to reveal a reason for this drastic change in water quality. One logical explanation could be that portions of the abandoned underground mine roof collapsed, providing available alkaline roof material. Mine waters flowing through fragmented alkaline roof falls are being neutralized. Provided this is a correct assumption, it serves to further support the technical feasibility of mine roof collapse as an acid abatement technique.

Alkaline regrading and slurry trench construction were originally proposed for demonstration at Project Site #5. Figures 31 and 32 illustrate existing and final spoil contour and the approximate slurry trench profile. Detailed mapping in Figure 33 also shows the location

Figure 28. Photograph of demonstration project site no. 5.

of proposed slurry trench installation. It is estimated that total abatement construction costs for regrading and slurry trenching would be $96,100. However, since mine discharges from Site #5 are no longer acid this project site is not deemed feasible for demonstrating proposed acid mine drainage abatement techniques.

Figure 29. Aerial view of demonstration project site no. 5.

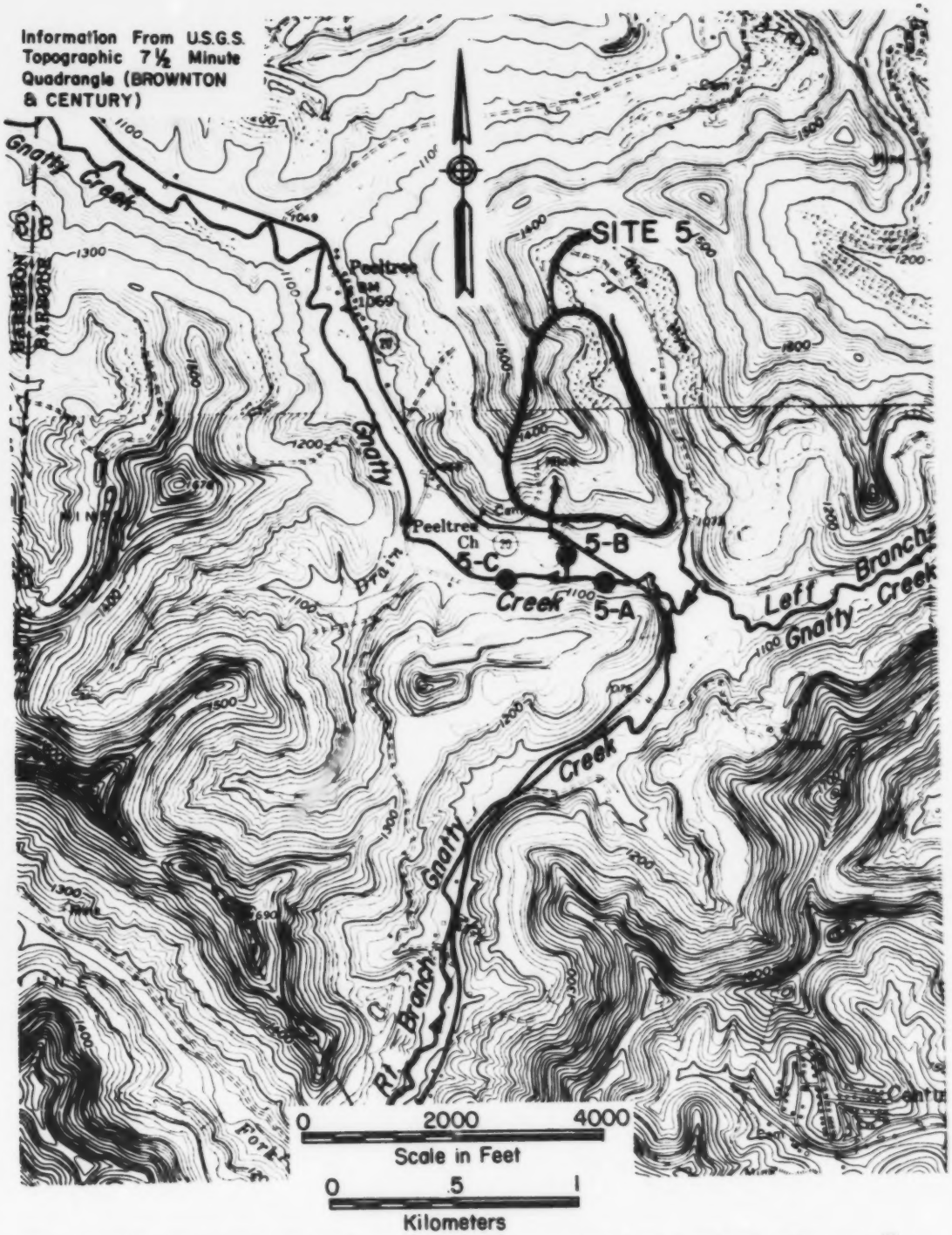
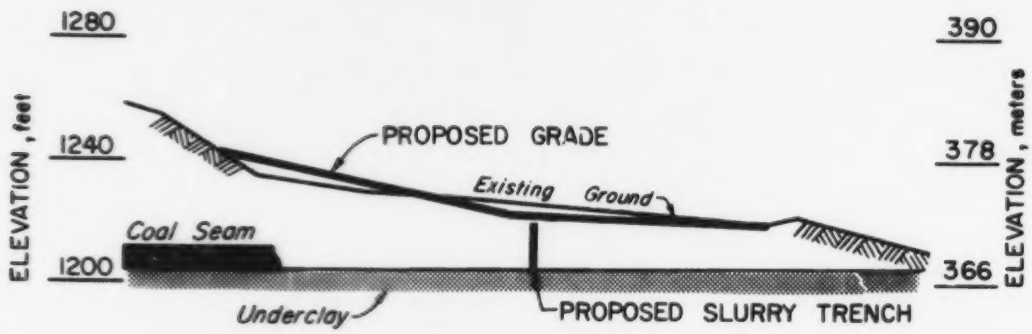
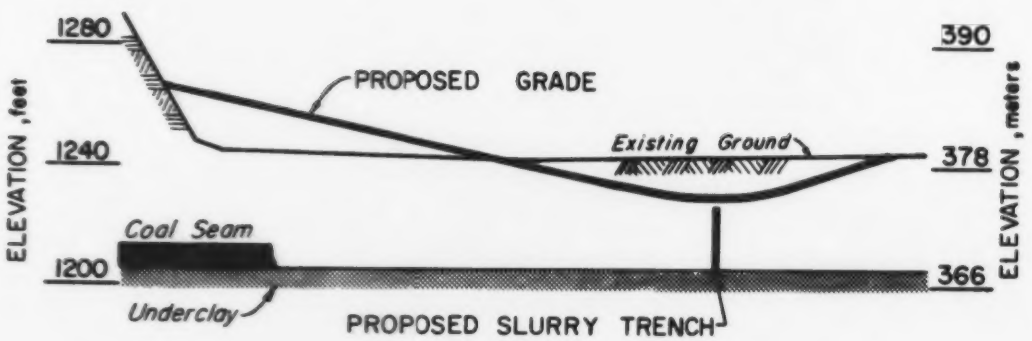


Figure 30. Sample station map for demonstration project site no. 5.



SECTION A-A'



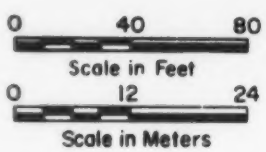


Figure 31. Cross sections of demonstration project site no. 5.

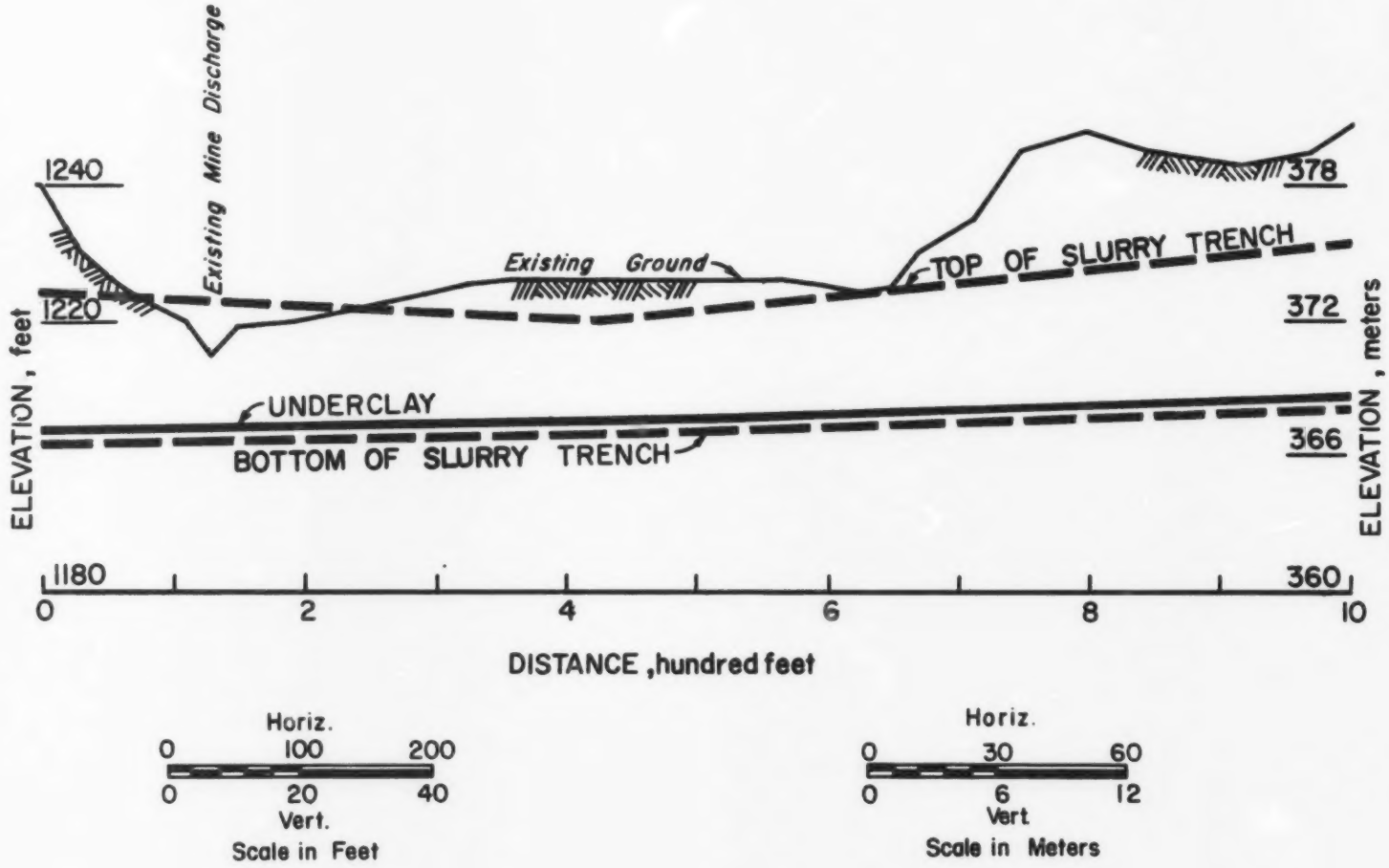


Figure 32. Profile of demonstration project site no. 5.

Figure 33. Plan of demonstration project site no. 5.

Estimated Construction Costs Site #5

Grading = 12,081 cu m @ $0.65/cu m = $ 7,900
(15,800 cu yd @ $0.50/cu yd)

Slurry Wall = 0.6 m wide x 6.10 m deep x 307.8 m
(2 ft. wide x 20 ft. deep x 1010 LF)

1,895 profile sq m @ $43.06/sq m = $81,600
(20,400 profile sq ft. @ $4.00/sq ft.)

Revegetation = 1.62 ha @ $1,235/ha = $ 2,000
(4 ac @ $500/ac)

Contingency = 5% = $ 4,600

Total = $96, 100

SECTION IX

REFERENCES

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3. Robins, John D., and Zaval, Frank J. Water Infiltration Control to Achieve Mine Water Pollution Control. Washington: U. S. Environmental Protection Agency, Office of Research Series R2-73-142 (14010 HHGO), 1973.

4. Skelly and Loy, Engineers and Consultants. Processes, Procedures, and Methods to Control Pollution from Mining Activities. Washington: U. S. Environmental Protection Agency EPA-430/9-73-011, October, 1973.

5. U. S. Department of Commerce, National Oceanic and Atmospheric Administration. Climatological Data. West Virginia. Ashville, North Carolina: Environmental Data Service.

6. U. S. Environmental Protection Agency, Division of Field Investigation. Summary Report - Monongahela River Mine Drainage Remedial Project. Cincinnati, Ohio, 1971.

SECTION X

GLOSSARY

1. Abatement (Mine Drainage Usage) - The reduction of the pollution effects on mine drainage.

2. Acid Mine Drainage - Any acid water draining or flowing on, or having drained or flowed off, any area of land affected by mining.

3. Alkaline Regrading - The technique of loosening and rearranging existing strip mine spoil material that contains alkaline soil and rock fragments with the specific purpose of enhancing neutralization of acid mine drainage.

4. Auger Mining - Generally practiced but not restricted to hilly coal bearing regions of the country. Utilizes a machine designed on the principle of the auger, which bores into an exposed coal seam, conveying the coal to a storage pile or bin for loading and transporting. May be used alone or in combination with conventional surface mining. When used alone, a single cut is made sufficient to expose the coal seam and provide operating space for the machine. When used in combination with surface mining the last cut pit provides the operating space.

5. Backfill - The operation of refilling an excavation. Also the material placed on an excavation in the process of backfilling.

6. Bench - The surface of an excavated area at some point between the material being mined and the original surface of the ground on which equipment can set, move or operate. A working road or base below a highwall as in contour stripping for coal.

7. Bentonite - A clay formed from the decomposition of volcanic ash. Also has great ability to absorb water and swell accordingly.

8. Contour Regrading - Movement of earth over a surface or depression in order to return the land surface to its approximate original shape.

9. Contour Stripping or Surface Mining - The removal of overburden and mining from a coal seam that outcrops or approaches the surface at approximately the same elevation, in steep or mountainous areas.

10. Crop Coal – Coal at the outcrop of the seam.

11. Deep Mine – An underground mine.

12. Highwall – The unexcavated face of exposed overburden and coal in a surface mine, or the face or bank on the uphill side of a contour strip mine excavation.

13. Overburden – The earth, rock, and other materials which lie above the coal.

14. Mine Roof Collapse – The technique of detonating explosive charges directly above a deep mine to collapse the immediate roof strata into mine entries. This can produce partial inundation of mine workings with mine waters.

15. Receiving Stream – A surface water flow that is augmented by a flow usually of lesser magnitude.

16. Slurry Trench – A narrow trench excavated in unconsolidated material with continuous application of bentonite clay (or a material with similar properties) slurry and backfilling. When tied into an underclay this provides an impermeable underground dam.

17. Spoil – The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

18. Strip Mine – A surface mine where the overburden is removed to expose the mineable material. Implies that there is a large amount of overburden with respect to the amount of mineable material.

19. Terrace Regrading – Movement of earth over a surface or depression to provide a flat bench or benches adjoining a highwall or along a hillside.

20. Underclay – A bed of clay highly siliceous in some cases and highly aluminous in many others, occurring immediately beneath a coal seam. These clays are often impermeable.

METRIC TABLE

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS)		by	TO OBTAIN (METRIC UNITS)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	kilowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilograms)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier

STA. NO. 1A

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	
10-16-73	F	0.283	3.0	2.9	600	147	0	0	79.9	20	19	4.7	1,201	294	1
11-19-73	F	0.011	3.5	3.2	300	293	0	0	29.3	29	0	0	950	929	2
1-08-74	F	0.016	3.4	3.1	268	360	0	0	26.9	36	-	-	650	874	3
2-12-74	F	0.011	3.6	2.9	298	291	0	0	35.7	35	-	-	725	709	4
3-27-74	F	0.010	3.5	2.9	500	416	0	0	29.8	25	-	-	1,025	852	5
4-30-74	F	0.566	3.2	2.9	500	245	0	0	49.4	24	-	-	1,025	501	6
5-23-74	R	0.736	-	3.1	300	191	0	0	50.8	32	-	-	700	445	7
6-12-74	F	0.510	-	2.9	440	194	0	0	44.2	20	-	-	900	396	8
6-24-74	F	0.013	-	3.6	140	154	0	0	20.3	22	-	-	425	469	9
7-08-74	F	0.453	-	3.0	600	235	0	0	45.3	18	-	-	1,025	401	10
7-22-74	F	0.368	-	2.9	600	191	0	0	48.4	15	-	-	1,450	461	11
8-04-74	F	0.366	-	2.8	900	308	0	0	51.8	18	-	-	1,475	505	12
8-21-74	F	0.227	-	2.9	562	110	0	0	52.6	10	3.4	0.7	1,625	318	13
Average		0.739	3.4	3.0	412	241	0	0	43.4	21	7.4	1.2	1,014	550	

STA. NO. 1B

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	
10-16-73	F	0.011	3.9	3.0	421	391	0	0	58.8	62	61	57	971	902	1
11-19-73	F	0.016	3.5	3.2	309	491	0	0	60.2	96	45.9	73	1,118	1,777	2
1-08-74	F	0.012	4.0	3.2	134	141	0	0	39.6	42	-	-	850	894	3
2-12-74	F	0.020	4.0	3.2	214	371	0	0	43.1	75	-	-	1,075	1,866	4
3-27-74	F	0.014	4.0	3.0	200	235	0	0	33.9	40	-	-	925	1,086	5
4-30-74	F	0.011	3.8	3.0	100	96	0	0	43.5	42	-	-	975	930	6
5-23-74	R	0.010	-	3.1	210	180	0	0	41.6	36	-	-	900	770	7
6-12-74	F	0.011	-	3.2	200	196	0	0	46.9	46	-	-	1,050	1,027	8
6-24-74	F	0.019	-	3.2	180	290	0	0	25.8	42	-	-	800	1,291	9
7-08-74	F	0.87	-	2.9	280	212	0	0	39.2	30	-	-	975	739	10
7-22-74	F	0.736	-	3.0	240	153	0	0	53.5	34	-	-	1,500	954	11
8-04-74	F	0.538	-	3.0	500	232	0	0	67.2	31	-	-	1,175	546	12
8-21-74	F	0.45	-	3.0	214	84	0	0	69.4	27	45.9	18	1,450	567	13
Average		0.012	3.9	3.1	246	236	0	0	48.5	46	50.9	49	1,059	1,027	

STA. NO. 1C

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	
10-16-73	F	-	3.2	3.1	600	-	0	0	22.5	-	6.72	-	1,073	-	1
11-19-73	F	0.026	4.4	3.6	200	445	0	0	18.9	42	11.2	25	624	1,388	2
1-08-74	F	0.070	4.7	4.4	50	302	8	48	15.2	92	-	-	450	2,718	3
2-12-74	F	0.066	4.6	4.0	92	524	0	0	22.7	129	-	-	525	2,991	4
3-27-74	F	0.055	4.4	3.8	80	379	0	0	15.1	72	-	-	425	2,016	5
4-30-74	F	0.032	3.8	3.4	115	320	0	0	15.8	44	-	-	600	1,658	6
5-23-74	R	0.044	-	6.0	32	123	48	184	23.3	89	-	-	350	1,344	7
6-12-74	F	0.035	-	3.8	100	303	0	0	12.9	39	-	-	525	1,592	8
6-24-74	F	0.152	-	6.2	20	262	42	549	5.6	73	-	-	325	4,251	9
7-08-74	F	0.041	-	3.6	140	500	0	0	12.4	44	-	-	600	2,142	10
7-22-74	F	0.052	-	3.7	120	534	0	0	8.2	37	-	-	1,125	5,006	11
8-04-74	F	0.041	-	3.6	130	464	0	0	16.1	58	-	-	900	3,213	12
8-21-74	F	0.016	-	3.0	176	241	0	0	9.4	13	7.8	11	1,400	1,780	13
Average		0.053	4.2	4.0	143	366	8	60	15.2	61	8.6	18	679	2,508	

[a] MULTIPLY BY 10^{-3}

STA. NO. 1A — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	µmhos	J T U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	3,100	-
3	-	-	-	-	-	-	-	-	-	-	2,500	-
4	-	-	-	-	-	-	-	-	-	-	1,400	-
5	-	-	-	-	-	-	-	-	-	-	2,700	-
6	-	-	-	-	-	-	-	-	-	-	1,400	-
7	-	-	-	-	-	-	-	-	-	-	1,500	-
8	-	-	-	-	-	-	-	-	-	-	1,900	-
9	-	-	96	106	3.3	3.6	11.7	13	137	151	750	59
10	-	-	150	59	-	-	-	-	-	-	2,300	2
11	-	-	360	114	10	3.2	42.4	14	22.8	7.3	4,550	11
12	-	-	78.3	27	-	-	-	-	-	-	5,100	12
13	93.4	18	320	63	9	1.8	51.3	10	301	59	8,200	29
	93.4	18	201	74	7.4	2.9	35.1	12	154	72	2,958	23

STA. NO. 1B — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	µmhos	J T U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	2,791	-
3	-	-	-	-	-	-	-	-	-	-	2,600	-
4	-	-	-	-	-	-	-	-	-	-	1,600	-
5	-	-	-	-	-	-	-	-	-	-	2,200	-
6	-	-	-	-	-	-	-	-	-	-	1,800	-
7	-	-	-	-	-	-	-	-	-	-	1,800	-
8	-	-	-	-	-	-	-	-	-	-	1,850	-
9	-	-	179	284	3.5	5.7	68	110	44.2	71	1,150	25
10	-	-	127	104	-	-	-	-	-	-	2,100	2
11	-	-	390	248	5	3.2	9	5.8	40.4	26	3,900	0
12	-	-	74.8	35	-	-	-	-	-	-	5,200	15
13	11.6	4.5	240	94	5.2	2	10.2	4	3.4	1.3	6,500	0
	11.6	4.5	204	159	4.6	3.6	29.1	40	29.3	33	2,791	8

STA. NO. 1C — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	µmhos	J T U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	1,100	-
3	-	-	-	-	-	-	-	-	-	-	750	-
4	-	-	-	-	-	-	-	-	-	-	950	-
5	-	-	-	-	-	-	-	-	-	-	1,100	-
6	-	-	-	-	-	-	-	-	-	-	1,200	-
7	-	-	-	-	-	-	-	-	-	-	850	-
8	-	-	-	-	-	-	-	-	-	-	1,150	-
9	-	-	96	1,256	1.3	17	22	288	904	11,825	600	42
10	-	-	127	453	-	-	-	-	-	-	1,400	8
11	-	-	350	1,557	4	18	12.8	57	34.2	152	2,900	9
12	-	-	84.1	300	-	-	-	-	-	-	4,100	33
13	12.4	17	390	534	4.5	6.2	13.1	18	66.2	118	4,800	35
	12.4	17	209	820	3.3	14	16	121	341	4,032	1,742	25

STA. NO. 2A — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg/day	ALKALINITY CONC. mg/l	ALKALINITY LOAD kg/day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg/day	FERROUS IRON CONC mg/l	FERROUS IRON LOAD kg/day	SULFATES CONC mg/l	SULFATES LOAD kg/day	REF NO
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-19-73	F	0.030	4.7	5.4	100	259	10	26	24	62	0	0	775	2,009	2
1-08-74	F	0.108	5.3	5.9	18	169	72	674	15.2	142	-	-	450	4,214	3
2-12-74	F	0.091	5.0	5.3	94	655	40	279	35.7	249	-	-	675	4,704	4
3-27-74	F	0.074	6.2	5.6	40	257	60	386	22.4	144	-	-	675	4,340	5
4-30-74	F	0.041	5.7	5.7	100	352	72	253	34.7	122	-	-	775	2,729	6
5-23-74	R	0.075	-	6.1	24	156	96	624	9.7	63	-	-	675	4,390	7
6-12-74	F	0.032	-	5.9	18	50	104	287	12.4	34	-	-	775	2,141	8
6-24-74	F	0.113	-	6.6	30	293	128	1,252	5.4	53	-	-	550	5,379	9
7-08-74	F	0.024	-	6.1	42	88	102	214	7.8	16	-	-	650	1,787	10
7-22-74	F	0.018	-	6.4	24	38	114	181	11.1	18	-	-	1,100	1,748	11
8-04-74	F	0.018	-	6.2	42	66	114	178	11.8	19	-	-	950	1,487	12
8-21-74	F	0.016	-	6.2	28	38	162	222	9.9	14	4.5	6.2	1,375	1,883	13
Average		0.053	5.4	6.0	47	202	90	381	16.7	78	2.3	3.1	802	3,068	

STA. NO. 2B — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg/day	ALKALINITY CONC. mg/l	ALKALINITY LOAD kg/day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg/day	FERROUS IRON CONC mg/l	FERROUS IRON LOAD kg/day	SULFATES CONC mg/l	SULFATES LOAD kg/day	REF NO
10-16-73	F	0.850	2.5	2.7	800	587	0	0	164	120	14.6	11	1,598	1,172	1
11-19-73	F	0.481	2.5	2.9	700	291	0	0	264	110	7.84	3.3	1,876	780	2
1-08-74	F	0.538	2.9	3.0	554	257	0	0	136	63	-	-	1,225	569	3
2-12-74	F	0.425	3.0	2.8	642	235	0	0	178	65	-	-	1,775	651	4
3-27-74	F	0.312	2.7	2.7	600	161	0	0	89	24	-	-	1,775	477	5
4-30-74	F	0.255	2.5	2.7	800	176	0	0	141	31	-	-	1,825	402	6
5-23-74	R	0.368	-	2.8	740	235	0	0	94.5	30	-	-	1,775	564	7
6-12-74	F	0.255	-	2.7	800	176	0	0	135	30	-	-	1,950	429	8
6-24-74	F	0.481	-	2.8	820	341	0	0	94.7	39	-	-	1,800	748	9
7-08-74	F	0.255	-	2.6	980	216	0	0	77.9	17	-	-	1,700	374	10
7-22-74	F	0.255	-	2.6	920	202	0	0	120	26	-	-	2,050	451	11
8-04-74	F	0.227	-	2.6	1,100	215	0	0	135	26	-	-	1,775	347	12
8-21-74	F	0.143	-	2.7	792	97	0	0	84.7	10	2.2	0.3	2,250	275	13
Average		0.373	2.7	2.7	788	245	0	0	132	45	8.2	4.9	1,798	557	

STA. NO. 2C — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg/day	ALKALINITY CONC. mg/l	ALKALINITY LOAD kg/day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg/day	FERROUS IRON CONC mg/l	FERROUS IRON LOAD kg/day	SULFATES CONC mg/l	SULFATES LOAD kg/day	REF NO
10-16-73	F	-	4.5	4.1	300	-	-	-	23.6	-	2.24	-	1,075	-	1
11-19-73	F	0.035	5.4	6.3	100	301	50	150	6.9	21	0	0	673	2,024	2
1-08-74	F	0.114	4.5	5.5	34	334	30	295	20.1	198	-	-	775	7,617	3
2-12-74	F	0.090	4.7	4.7	90	698	8	62	39.3	305	-	-	850	6,588	4
3-27-74	F	0.075	5.3	4.9	54	350	10	65	39.6	257	-	-	650	4,212	5
4-30-74	F	0.044	4.7	4.4	200	758	0	0	37.3	141	-	-	975	3,695	6
5-23-74	R	0.065	-	5.7	38	280	34	250	19	140	-	-	725	5,336	7
6-12-74	F	0.033	-	4.6	100	281	10	28	22.1	62	-	-	850	2,390	8
6-24-74	F	0.117	-	6.4	22	222	82	828	8.5	86	-	-	800	8,078	9
7-08-74	F	0.029	-	4.7	60	153	10	25	17.5	46	-	-	300	2,269	10
7-22-74	F	0.021	-	4.7	64	116	10	18	18.4	33	-	-	1,150	2,081	11
8-04-74	F	0.019	-	4.5	80	131	0	0	28.2	46	-	-	1,075	1,761	12
8-21-74	F	0.018	-	5.2	24	38	28	44	20.5	32	2.2	3.4	1,700	2,660	13
Average		0.057	4.9	5.1	90	305	23	147	23.2	114	1.5	1.7	938	4,061	

* MULTIPLY BY 10^{-3}

STA. NO. 2A — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	1,200	–
3	–	–	–	–	–	–	–	–	–	–	1,900	–
4	–	–	–	–	–	–	–	–	–	–	1,200	–
5	–	–	–	–	–	–	–	–	–	–	1,500	–
6	–	–	–	–	–	–	–	–	–	–	1,450	–
7	–	–	–	–	–	–	–	–	–	–	1,300	–
8	–	–	–	–	–	–	–	–	–	–	1,550	–
9	–	–	149	1,457	2.3	23	0.9	8.8	13.5	132	900	5
10	–	–	106	223	–	–	–	–	–	–	1,600	1
11	–	–	390	620	5	8	4.3	6.8	135	215	3,300	22
12	–	–	56.8	39	–	–	–	–	–	–	4,250	28
13	11.8	16	390	534	6	8.2	4.5	6.2	56.2	77	5,200	51
	11.8	16	218	585	4.4	13	3.2	7.3	68.2	141	2,113	21

STA. NO. 2B — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	7,500	–
3	–	–	–	–	–	–	–	–	–	–	3,950	–
4	–	–	–	–	–	–	–	–	–	–	2,200	–
5	–	–	–	–	–	–	–	–	–	–	3,200	–
6	–	–	–	–	–	–	–	–	–	–	2,600	–
7	–	–	–	–	–	–	–	–	–	–	2,900	–
8	–	–	–	–	–	–	–	–	–	–	3,000	–
9	–	–	282	117	14.1	5.9	26.2	11	17.1	7.1	2,500	13
10	–	–	93.8	21	–	–	–	–	–	–	3,200	23
11	–	–	460	101	18	4	29.1	6.4	16.4	3.6	7,000	9
12	–	–	94.1	18	–	–	–	–	–	–	8,000	32
13	118	14	470	57	19.1	2.3	31.3	3.8	18.4	2.2	9,900	15
	118	14	280	63	17.1	4.1	28.9	7.1	17.1	4.3	4,663	18

STA. NO. 2C — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC. COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	1,100	–
3	–	–	–	–	–	–	–	–	–	–	2,200	–
4	–	–	–	–	–	–	–	–	–	–	1,400	–
5	–	–	–	–	–	–	–	–	–	–	1,800	–
6	–	–	–	–	–	–	–	–	–	–	1,550	–
7	–	–	–	–	–	–	–	–	–	–	1,450	–
8	–	–	–	–	–	–	–	–	–	–	1,700	–
9	–	–	146	1,474	2.9	29	16	162	14.1	142	1,050	21
10	–	–	68.2	173	–	–	–	–	–	–	1,800	25
11	–	–	400	724	7	13	6.7	12	72.4	131	3,500	24
12	–	–	64.4	105	–	–	–	–	–	–	4,300	39
13	14.6	23	340	532	6.9	11	7.6	12	108	169	5,200	149
	14.6	23	204	602	5.6	18	10.1	62	64.8	147	2,254	52

STA. NO. 2D — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg /day	ALKALINITY CONC. mg/l	ALKALINITY LOAD kg /day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg /day	FERROUS IRON CONC. mg/l	FERROUS IRON LOAD kg /day	SULFATES CONC mg/l	SULFATES LOAD kg /day	REF NO.
10-18-73	F	-	2.5	2.6	700	-	0	-	199	-	11.2	-	1,523	-	1
11-19-73	F	0.085[a]	3.0	3.0	600	44	0	0	100	7.3	-	-	1,448	106	2
1-08-74	F	0.113[a]	3.4	3.0	544	53	0	0	268	28	-	-	1,375	134	3
2-12-74	F	0.028[a]	3.0	2.9	512	13	0	0	139	3.4	-	-	1,650	40	4
3-27-74	F	0.008[a]	3.2	2.9	400	3	0	0	39	0.3	-	-	1,300	9.5	5
4-30-74	F	0.003[a]	2.5	2.8	700	2	0	0	53.8	0.1	-	-	1,475	3.6	6
5-23-74	R	0.028[a]	-	2.8	700	17	0	0	54.1	1.3	-	-	1,275	31	7
6-12-74	F	0.028[a]	-	2.8	560	14	0	0	34	0.8	-	-	1,375	34	8
6-24-74	F	0.057[a]	-	3.1	300	15	0	0	16.6	0.8	-	-	1,100	54	9
7-08-74	F	Dry	-	-	-	-	-	-	-	-	-	-	-	-	10
7-22-74	F	Dry	-	-	-	-	-	-	-	-	-	-	-	-	11
8-04-74	F	Dry	-	-	-	-	-	-	-	-	-	-	-	-	12
8-21-74	F	Dry	-	-	-	-	-	-	-	-	-	-	-	-	13
Average		0.044[a]	2.9	2.9	557	20	0	0	103	5.3	11.2	-	1,391	52	

STA. NO. 2D' — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg /day	ALKALINITY CONC mg/l	ALKALINITY LOAD kg /day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg /day	FERROUS IRON CONC mg/l	FERROUS IRON LOAD kg /day	SULFATES CONC mg/l	SULFATES LOAD kg /day	REF NO.
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
2-12-74	F	0.821[a]	3.5	3.0	1,700	1,205	0	0	530	376	408	289	2,575	1,826	4
3-27-74	F	0.821[a]	3.2	2.7	700	496	0	0	121	86	-	-	1,735	1,230	5
4-30-74	F	0.878[a]	3.0	2.6	700	531	0	0	298	226	-	-	1,650	1,251	6
5-23-74	R	0.340[a]	-	2.8	1,050	308	0	0	347	102	-	-	2,175	638	7
6-12-74	F	0.368[a]	-	2.7	1,080	343	0	0	308	98	-	-	2,750	874	8
6-24-74	F	0.368[a]	-	2.7	1,240	394	0	0	186	59	-	-	2,500	795	9
7-08-74	F	0.340[a]	-	2.6	1,380	405	0	0	151	44	-	-	1,875	550	10
7-22-74	F	0.283[a]	-	2.6	1,000	245	0	0	264	65	-	-	2,450	599	11
8-04-74	F	0.113[a]	-	2.6	800	88	0	0	238	23	-	-	2,350	230	12
8-21-74	F	0.028[a]	-	2.7	688	17	0	0	121	3	28	0.7	2,500	61	13
Average		0.436[a]	3.2	2.7	1,044	403	0	0	256	108	218	145	2,256	805	

STA. NO. 2E — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW M^3/s	pH FIELD	pH LAB	ACIDITY CONC. mg/l	ACIDITY LOAD kg /day	ALKALINITY CONC mg/l	ALKALINITY LOAD kg /day	TOTAL IRON CONC mg/l	TOTAL IRON LOAD kg /day	FERROUS IRON CONC mg/l	FERROUS IRON LOAD kg /day	SULFATES CONC mg/l	SULFATES LOAD kg /day	REF NO.
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-19-73	F	0.036	4.7	5.9	100	313	10	31	14.3	45	0	0	724	2,266	2
1-08-74	F	0.129	4.8	5.6	20	223	26	290	20.1	224	-	-	775	8,641	3
2-12-74	F	0.098	4.5	4.3	160	1,357	0	0	85.1	722	-	-	1,350	11,454	4
3-27-74	F	0.083	4.7	3.5	128	920	0	0	37.3	268	-	-	825	5,930	5
4-30-74	F	0.053	4.0	3.2	200	910	0	0	54.5	248	-	-	1,450	6,594	6
5-23-74	R	0.089	-	4.4	44	338	0	0	22.2	170	-	-	775	5,950	7
6-12-74	F	0.037	-	3.2	140	442	0	0	38	120	-	-	1,075	3,391	8
6-24-74	F	0.121	-	5.6	52	544	28	293	17.4	182	-	-	800	8,372	9
7-08-74	F	0.033	-	3.1	260	744	0	0	43.4	124	-	-	1,125	3,218	10
7-22-74	F	0.024	-	3.2	200	411	0	0	42.3	87	-	-	1,500	3,081	11
8-04-74	F	0.020	-	3.2	94	163	0	0	40.5	70	-	-	1,275	2,213	12
8-21-74	F	0.018	-	3.4	104	165	0	0	30.6	49	2.2	3.5	1,500	2,384	13
Average		0.062	4.5	4.1	125	544	5	51	37.1	192	1.1	1.8	1,098	5,291	

[a] MULTIPLY BY 10^{-2}

STA. NO. 2D — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	2,300	–
3	–	–	–	–	–	–	–	–	–	–	4,600	–
4	–	–	–	–	–	–	–	–	–	–	1,900	–
5	–	–	–	–	–	–	–	–	–	–	2,600	–
6	–	–	–	–	–	–	–	–	–	–	2,350	–
7	–	–	–	–	–	–	–	–	–	–	2,600	–
8	–	–	–	–	–	–	–	–	–	–	2,400	–
9	–	–	254	12	9	0.4	16.8	0.8	20.9	1	1,650	0
10	–	–	–	–	–	–	–	–	–	–	–	–
11	–	–	–	–	–	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–
	–	–	254	12	9	0.4	16.8	0.8	20.9	1	2,550	0

STA. NO. 2D' — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	2,700	–
5	–	–	–	–	–	–	–	–	–	–	3,000	–
6	–	–	–	–	–	–	–	–	–	–	2,750	–
7	–	–	–	–	–	–	–	–	–	–	3,100	–
8	–	–	–	–	–	–	–	–	–	–	3,050	–
9	–	–	326	104	4.4	1.4	33.4	11	4.8	1.5	2,900	20
10	–	–	95.8	28	–	–	–	–	–	–	3,200	29
11	–	–	430	105	5	1.2	29.9	7.3	139	34	8,100	17
12	–	–	94.7	9.3	–	–	–	–	–	–	8,300	28
13	56.5	1.4	452	11	5.5	0.1	25.5	0.6	67.2	1.6	8,700	0
	56.5	1.4	280	51	5	0.9	29.6	6.3	70.3	12	4,580	19

STA. NO. 2E — **SAMPLING DATA**

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	1,200	–
3	–	–	–	–	–	–	–	–	–	–	1,150	–
4	–	–	–	–	–	–	–	–	–	–	1,500	–
5	–	–	–	–	–	–	–	–	–	–	1,800	–
6	–	–	–	–	–	–	–	–	–	–	1,750	–
7	–	–	–	–	–	–	–	–	–	–	1,500	–
8	–	–	–	–	–	–	–	–	–	–	1,950	–
9	–	–	169	1,769	2.9	30	2.4	25	77	804	1,200	42
10	–	–	76.2	218	–	–	–	–	–	–	2,050	8
11	–	–	360	739	6	12	8.3	17	144	296	3,600	24
12	–	–	69.3	120	–	–	–	–	–	–	4,700	66
13	19.7	31	270	429	7.1	11	7.9	13	157	250	5,900	9
	19.7	31	189	655	5.3	18	6.2	18	126	450	2,375	30

STA. NO. 3A

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO.
		m^3/s	FIELD	LAB	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-19-73	F	0.694	5.0	6.4	200	11,981	32	1,917	2.86	171	0	0	426	25,518	2
1-08-74	F	1.215	5.0	6.4	10	1,049	70	7,342	6.44	675	-	-	400	41,956	3
2-12-74	F	0.952	5.8	5.8	10	822	86	7,065	5.24	430	-	-	400	32,861	4
3-27-74	F	0.750	5.7	6.1	14	907	100	6,479	4.9	317	-	-	350	22,677	5
4-30-74	F	0.368	6.2	6.6	6	191	170	5,403	2.5	80	-	-	925	29,401	6
5-23-74	R	0.742	-	5.9	18	1,153	94	6,022	2.9	186	-	-	525	33,631	7
6-12-74	F	0.357	-	6.5	4	123	138	4,251	3.7	114	-	-	725	22,335	8
6-24-74	F	3.087	-	6.4	12	3,198	60	15,990	3.2	853	-	-	250	66,626	9
7-08-74	F	0.388	-	7.0	0	0	168	5,627	2	67	-	-	575	19,260	10
7-22-74	F	0.283	-	7.2	0	0	158	3,863	1.5	37	-	-	850	20,783	11
8-04-74	F	0.137	-	6.5	20	236	152	1,795	1.8	21	-	-	825	9,743	12
8-21-74	F	0.194	-	6.8	8	134	140	2,345	2.3	39	0	0	850	14,236	13
Average		0.784	5.5	6.5	25	1,650	114	5,675	3.3	249	0	0	592	28,252	

STA. NO. 3B

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO.
		m^3/s	FIELD	LAB	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	
10-17-73	F	0.425	5.0	3.7	400	147	0	0	106	39	77.3	28	1,024	376	1
11-19-73	F	0.396	4.5	4.2	300	103	0	0	160	55	93	32	1,650	565	2
1-08-74	F	0.198	4.5	5.6	106	18	22	4	62.2	11	-	-	1,175	201	3
2-12-74	F	0.283	5.0	5.5	50	12	60	15	53	13	-	-	1,225	300	4
3-27-74	F	0.227	5.5	5.5	34	7	38	7	32.4	6.3	-	-	1,100	215	5
4-30-74	F	0.198	5.2	6.4	100	17	54	9	22.6	3.9	-	-	1,550	265	6
5-23-74	R	0.198	-	5.3	40	7	12	2	22.9	3.9	-	-	1,150	197	7
6-12-74	F	0.227	-	6.0	12	2	22	4	21.4	4.2	-	-	1,200	235	8
6-24-74	F	0.312	-	6.3	24	6	40	11	12.9	3.5	-	-	1,425	383	9
7-08-74	F	0.142	-	6.7	12	1	24	3	6	0.7	-	-	975	119	10
7-22-74	F	0.142	-	4.6	38	5	4	1	22.4	2.7	-	-	1,375	168	11
8-04-74	F	0.085	-	4.8	60	4	10	1	31.7	2.3	-	-	1,475	108	12
8-21-74	F	0.095	-	3.3	58	4	0	0	31.2	2.3	31.4	2.3	1,775	130	13
Average		0.224	5.0	5.2	95	26	22	4	45	11	67.2	21	1,315	251	

STA. NO. 3C

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO
		m^3/s	FIELD	LAB	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	
10-17-73	F	-	5.3	6.4	200	-	48	-	3.4	-	-	-	773	-	1
11-19-73	F	0.700	5.0	6.4	200	12,078	28	1,691	3.4	205	0	0	549	33,155	2
1-08-74	F	1.218	5.0	6.3	10	1,051	64	6,729	6.44	677	-	-	450	47,311	3
2-12-74	F	0.954	5.3	5.9	10	824	80	6,592	6.81	561	-	-	350	28,839	4
3-27-74	F	0.753	5.7	6.5	10	650	98	6,374	5.1	332	-	-	400	26,015	5
4-30-74	F	0.371	6.5	6.9	4	128	170	5,445	2.7	87	-	-	925	29,627	6
5-23-74	R	0.745	-	6.1	14	900	96	6,173	3.8	244	-	-	500	32,152	7
6-12-74	F	0.360	-	6.6	2	62	130	4,037	3.4	106	-	-	550	17,078	8
6-24-74	F	3.087	-	6.4	10	2,666	62	16,523	3.5	933	-	-	300	79,952	9
7-08-74	F	0.391	-	7.1	0	0	156	5,264	1.9	64	-	-	525	17,714	10
7-22-74	F	0.286	-	7.1	0	0	150	3,704	1.9	47	-	-	700	17,286	11
8-04-74	F	0.138	-	6.5	14	166	180	1,901	2.5	30	-	-	650	7,724	12
8-21-74	F	0.195	-	7.0	0	0	134	2,264	2.2	37	0	0	625	10,514	13
Average		0.767	5.5	6.6	36	1,544	106	5,557	3.6	277	0	0	561	28,947	

* MULTIPLY BY 10^{-6}

STA. NO. 3A

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	800	–
3	–	–	–	–	–	–	–	–	–	–	1,250	–
4	–	–	–	–	–	–	–	–	–	–	700	–
5	–	–	–	–	–	–	–	–	–	–	880	–
6	–	–	–	–	–	–	–	–	–	–	1,100	–
7	–	–	–	–	–	–	–	–	–	–	1,050	–
8	–	–	–	–	–	–	–	–	–	–	1,300	–
9	–	–	72	19,188	0.8	213	0.1	27	22.2	5,916	450	8
10	–	–	43.6	1,460	–	–	–	–	–	–	1,250	9
11	–	–	280	6,846	2.6	64	0.1	2.5	19.6	479	2,400	8
12	–	–	48.4	572	–	–	–	–	–	–	3,300	5
13	11.3	189	290	4,857	2.5	42	0.1	1.7	1	17	3,600	0
	11.3	189	147	6,585	2	106	0.1	10	14.3	2,137	1,507	6

STA. NO. 3B

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	4,700	–
3	–	–	–	–	–	–	–	–	–	–	3,650	–
4	–	–	–	–	–	–	–	–	–	–	1,650	–
5	–	–	–	–	–	–	–	–	–	–	2,400	–
6	–	–	–	–	–	–	–	–	–	–	1,700	–
7	–	–	–	–	–	–	–	–	–	–	2,100	–
8	–	–	–	–	–	–	–	–	–	–	2,000	–
9	–	–	232	62	8.7	2.3	0.1	0.03	23	6.2	1,800	58
10	–	–	73.8	9	–	–	–	–	–	–	2,050	0
11	–	–	450	55	12	1.5	0.1	0.01	215	26	4,000	19
12	–	–	69.2	5.1	–	–	–	–	–	–	5,600	51
13	61.4	4.5	430	32	11.3	0.8	0.1	0.01	67.6	5	7,200	35
	61.4	4.5	251	33	10.7	1.5	0.1	0.02	102	12	3,238	33

STA. NO. 3C

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	800	–
3	–	–	–	–	–	–	–	–	–	–	900	–
4	–	–	–	–	–	–	–	–	–	–	700	–
5	–	–	–	–	–	–	–	–	–	–	900	–
6	–	–	–	–	–	–	–	–	–	–	1,100	–
7	–	–	–	–	–	–	–	–	–	–	1,150	–
8	–	–	–	–	–	–	–	–	–	–	1,300	–
9	–	–	74	19,721	0.9	240	0.8	213	55.9	14,898	500	8
10	–	–	32.5	1,097	–	–	–	–	–	–	1,250	0
11	–	–	250	6,174	2.7	67	0.1	2.5	25.4	627	2,400	6
12	–	–	46.4	551	–	–	–	–	–	–	3,100	22
13	11.2	188	230	3,869	2.2	37	0.1	1.7	41.8	703	3,500	0
	11.2	188	127	6,282	1.9	115	0.3	72	41	5,409	1,467	7

STA. NO. 4A — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO.
		M^3/s	FIELD	LAB	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	
10-16-73	F	0.017	6.5	6.5	100	147	116	170	38.7	57	30.2	44	973	1,427	1
11-20-73	F	0.013	6.0	6.7	100	115	150	172	39.1	45	22.4	26	1,300	1,494	2
1-08-74	F	0.027	5.9	6.8	60	138	288	662	20.1	46	–	–	800	1,839	3
2-12-74	F	0.053	6.2	6.2	64	294	360	1,655	23.2	107	–	–	650	2,988	4
3-27-74	F	0.064	7.0	6.4	46	253	464	2,553	15.1	83	–	–	500	2,751	5
4-30-74	F	0.037	7.0	6.9	100	320	470	1,505	18.5	59	–	–	1,050	3,363	6
5-23-74	R	0.027	–	6.7	50	115	450	1,034	19.2	44	–	–	600	1,379	7
6-12-74	F	0.033	–	6.8	22	62	456	1,293	20.3	58	–	–	600	1,702	8
6-24-74	F	0.040	–	6.8	58	203	358	1,252	19.4	68	–	–	700	2,447	9
7-08-74	F	0.044	–	7.0	0	0	464	1,758	21.2	80	–	–	675	2,558	10
7-22-74	F	0.030	–	7.0	0	0	490	1,282	19.3	51	–	–	825	2,158	11
8-04-74	F	0.031	–	6.8	28	76	524	1,422	20.6	56	–	–	750	2,035	12
8-21-74	F	0.025	–	6.9	0	0	450	957	16.8	36	15.4	33	900	1,914	13
Average		0.034	6.4	6.7	48	133	388	1,209	22.4	61	22.7	34	794	2,158	

STA. NO. 4B — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO.
		M^3/s	FIELD	LAB	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	
10-16-73	F	0.850	3.3	2.8	300	220	0	0	134	98	4.48	3.3	1,276	936	1
11-20-73	F	0.255	3.4	3.2	500	110	0	0	122	27	32.5	7.2	1,700	374	2
1-08-74	F	0.453	3.3	3.1	496	194	0	0	164	64	–	–	1,725	675	3
2-12-74	F	0.510	3.5	3.0	500	220	0	0	155	68	–	–	1,575	693	4
3-27-74	F	0.425	3.5	2.9	400	147	0	0	72.4	27	–	–	1,900	697	5
4-30-74	F	0.170	3.2	2.9	300	44	0	0	92.3	14	–	–	2,250	330	6
5-23-74	R	0.368	–	2.9	360	114	0	0	82.2	26	–	–	1,450	461	7
6-12-74	F	0.340	–	2.9	340	100	0	0	122	36	–	–	1,575	462	8
6-24-74	F	0.623	–	2.9	540	290	0	0	111	60	–	–	1,650	888	9
7-08-74	F	0.340	–	2.9	420	123	0	0	66.4	20	–	–	1,725	506	10
7-22-74	F	0.255	–	2.8	420	92	0	0	84.7	19	–	–	1,950	429	11
8-04-74	F	0.227	–	2.9	500	98	0	0	88.5	17	–	–	1,850	362	12
8-21-74	F	0.198	–	2.8	344	59	0	0	69.8	12	59.4	10	1,950	334	13
Average		0.386	3.4	2.9	417	139	0	0	105	38	32.1	6.8	1,737	550	

STA. NO. 4C — **SAMPLING DATA**

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF. NO.
		M^3/s	FIELD	LAB	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	
10-16-73	F	0.025	5.9	6.5	100	220	76	167	47.9	105	11.2	25	952	2,095	1
11-20-73	F	0.016	5.7	6.6	100	137	94	129	30.2	41	0	0	1,277	1,748	2
1-08-74	F	0.034	5.3	6.0	84	246	132	387	37.7	111	–	–	950	2,787	3
2-12-74	F	0.058	6.2	6.1	92	463	300	1,511	34.5	174	–	–	825	4,155	4
3-27-74	F	0.068	6.7	6.5	20	117	340	1,995	33.9	199	–	–	725	4,254	5
4-30-74	F	0.037	7.0	6.7	100	323	384	1,239	38.7	125	–	–	1,200	3,873	6
5-23-74	R	0.031	–	6.4	36	95	348	919	24.9	66	–	–	775	2,046	7
6-12-74	F	0.035	–	6.5	20	60	390	1,173	41.5	125	–	–	800	2,406	8
6-24-74	F	0.094	–	6.6	94	765	296	2,410	46.8	381	–	–	825	6,717	9
7-08-74	F	0.050	–	6.7	40	171	370	1,583	34.8	149	–	–	775	3,316	10
7-22-74	F	0.036	–	6.7	30	92	414	1,275	57.8	178	–	–	900	2,773	11
8-04-74	F	0.034	–	6.6	30	88	402	1,179	31.1	91	–	–	850	2,494	12
8-21-74	F	0.027	–	6.7	22	51	444	1,020	20.7	49	11.2	26	1,050	2,413	13
Average		0.042	6.1	6.5	59	218	307	1,153	37	138	7.5	17	916	3,160	

* MULTIPLY BY 10^{-3}

STA. NO. 4A

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg./day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	1,850	–
3	–	–	–	–	–	–	–	–	–	–	2,650	–
4	–	–	–	–	–	–	–	–	–	–	1,300	–
5	–	–	–	–	–	–	–	–	–	–	1,700	–
6	–	–	–	–	–	–	–	–	–	–	1,400	–
7	–	–	–	–	–	–	–	–	–	–	1,500	–
8	–	–	–	–	–	–	–	–	–	–	1,550	–
9	–	–	152	531	1.6	5.6	0.2	0.7	18.1	63	1,200	130
10	–	–	43.5	165	–	–	–	–	–	–	1,550	0
11	–	–	300	785	1.8	4.7	0	0	56.8	149	3,050	37
12	–	–	54.1	147	–	–	–	–	–	–	4,300	49
13	11.2	24	300	638	2.1	4.5	0.1	0.2	5.2	11	4,900	105
	11.2	24	170	453	1.8	4.9	0.1	0.3	26.7	74	2,246	64

STA. NO. 4B

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg./day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	2,600	–
3	–	–	–	–	–	–	–	–	–	–	2,700	–
4	–	–	–	–	–	–	–	–	–	–	2,300	–
5	–	–	–	–	–	–	–	–	–	–	3,900	–
6	–	–	–	–	–	–	–	–	–	–	2,650	–
7	–	–	–	–	–	–	–	–	–	–	2,850	–
8	–	–	–	–	–	–	–	–	–	–	2,900	–
9	–	–	236	127	8.2	4.4	15.9	8.6	127	68	2,400	10
10	–	–	75.4	22	–	–	–	–	–	–	2,950	9
11	–	–	440	97	9	2	7.6	1.7	102	22	6,100	6
12	–	–	75.3	15	–	–	–	–	–	–	7,600	23
13	117	20	430	74	8.2	1.4	7.5	1.3	139	24	8,800	9
	117	20	251	67	8.5	2.6	10.3	3.9	123	38	3,979	11

STA. NO. 4C

SAMPLING DATA

REF. NO.	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP. SOLIDS		SPEC. COND.	TURBIDITY
	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg./day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	CONC. mg/l	LOAD kg/day	µmhos	J.T.U.
1	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	–	–	–	–	2,400	–
3	–	–	–	–	–	–	–	–	–	–	2,900	–
4	–	–	–	–	–	–	–	–	–	–	1,400	–
5	–	–	–	–	–	–	–	–	–	–	1,600	–
6	–	–	–	–	–	–	–	–	–	–	1,500	–
7	–	–	–	–	–	–	–	–	–	–	1,700	–
8	–	–	–	–	–	–	–	–	–	–	1,650	–
9	–	–	153	1,246	2.1	17	1.4	11	94.9	773	1,350	115
10	–	–	74.3	318	–	–	–	–	–	–	1,700	18
11	–	–	310	955	2.5	7.7	1.5	4.6	159	490	3,250	19
12	–	–	54.8	161	–	–	–	–	–	–	4,200	79
13	11.3	26	430	988	2.4	5.5	2	4.6	56	129	5,000	180
	11.3	26	204	734	2.3	10	1.6	6.7	103	464	2,388	82

STA. NO. 5A

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-19-73	F	0.270	6.0	7.4	0	0	128	2,995	2.18	51	0	0	623	14,573	2
1-09-74	F	0.836	5.9	7.0	0	0	250	18,022	1.2	87	-	-	490	35,342	3
2-12-74	F	0.620	6.0	6.6	12	643	224	12,208	2.01	109	-	-	400	21,418	4
3-27-74	F	0.544	6.5	7.2	0	0	300	14,053	0.61	29	-	-	425	19,951	5
4-30-74	F	0.312	7.0	7.6	0	0	372	10,005	1.1	30	-	-	600	16,137	6
5-23-74	R	0.366	-	7.3	0	0	308	9,780	1.6	51	-	-	400	12,714	7
6-12-74	F	0.419	-	7.5	0	0	344	12,443	1.3	47	-	-	450	16,294	8
6-24-74	F	-	-	7.2	0	0	156	-	1.7	-	-	-	400	-	9
7-09-74	F	0.327	-	7.1	0	0	364	10,295	1.7	48	-	-	475	13,356	10
7-22-74	F	0.268	-	7.5	0	0	330	7,624	2	46	-	-	550	15,018	11
8-04-74	F	0.257	-	7.3	0	0	330	7,334	3	67	-	-	475	10,557	12
8-21-74	F	0.176	-	7.4	0	0	344	5,240	2.8	43	0	0	725	11,043	13
Average		0.430	6.3	7.3	1	54	291	9,999	1.8	55	0	0	505	15,340	

STA. NO. 5B

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	
10-17-73	F	0.885	5.9	6.2	200	147	136	100	83.9	62	26.9	20	1,351	991	1
11-19-73	F	0.705	5.4	6.4	100	61	54	33	57.7	35	31.4	19	1,575	963	2
1-08-74	F	0.65*	5.3	6.2	96	54	80	45	59	33	-	-	1,350	756	3
2-12-74	F	0.012	5.5	6.3	69	72	110	116	50	59	-	-	1,375	1,445	4
3-27-74	F	0.012	5.9	6.4	23	29	214	220	27.3	30	-	-	1,175	1,207	5
4-30-74	F	0.705	7.0	6.6	200	122	229	139	46.1	27	-	-	1,450	888	6
5-23-74	R	0.765	-	7.1	0	0	212	140	39.9	26	-	-	1,075	710	7
6-12-74	F	0.565	-	7.2	0	0	244	119	48	23	-	-	1,350	660	8
6-24-74	F	0.650	-	7.0	0	0	200	147	32.5	24	-	-	1,525	1,119	9
7-09-74	F	0.705	-	7.1	0	0	270	195	42.5	28	-	-	1,475	902	10
7-22-74	F	0.765	-	7.0	0	0	214	141	41.6	28	-	-	1,700	1,122	11
8-06-74	F	0.623	-	7.1	0	0	222	119	52.4	28	-	-	1,575	847	12
8-21-74	F	0.350	-	7.3	0	0	224	77	38.4	13	1.1	0.4	1,650	568	13
Average		0.750	5.9	6.6	53	37	185	120	49.3	32	19.8	13	1,433	937	

STA. NO. 5C

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		M^3/s	FIELD	LAB	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	CONC mg/l	LOAD kg / day	
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-19-73	F	0.277	5.7	7.7	0	0	126	3,016	3.77	90	0	0	561	13,189	2
1-08-74	F	0.841	6.0	7.0	0	0	256	18,590	1.84	134	-	-	490	35,582	3
2-12-74	F	0.632	6.0	6.7	12	654	216	11,777	3.4	185	0	0	350	19,083	4
3-27-74	F	0.558	6.2	7.6	0	0	274	13,196	3.04	146	-	-	350	16,858	5
4-30-74	F	0.320	7.0	7.4	0	0	330	9,117	2.1	58	-	-	475	13,124	6
5-23-74	R	0.374	-	7.2	0	0	256	8,254	2.6	84	-	-	350	11,286	7
6-12-74	F	0.425	-	7.6	0	0	328	12,029	2.7	99	-	-	400	14,670	8
6-24-74	F	-	-	7.3	0	0	210	-	2.7	-	-	-	425	-	9
7-09-74	F	0.334	-	7.4	0	0	354	10,502	3.4	98	-	-	575	16,546	10
7-22-74	F	0.275	-	7.4	0	0	310	7,367	3.3	78	-	-	600	14,256	11
8-04-74	F	0.264	-	6.9	0	0	266	6,592	5.7	130	-	-	500	13,658	12
8-21-74	F	0.190	-	7.5	0	0	314	4,890	4.4	66	0	0	775	12,070	13
Average		0.407	6.2	7.3	1	55	278	9,679	3.2	106	0	0	495	16,366	

* MULTIPLY BY 10^{-3}

STA. NO. 5A

SAMPLING DATA

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	1,000	-
3	-	-	-	-	-	-	-	-	-	-	1,650	-
4	-	-	-	-	-	-	-	-	-	-	950	-
5	-	-	-	-	-	-	-	-	-	-	1,000	-
6	-	-	-	-	-	-	-	-	-	-	1,050	-
7	-	-	-	-	-	-	-	-	-	-	1,100	-
8	-	-	-	-	-	-	-	-	-	-	1,200	-
9	-	-	114	-	0.7	-	0.3	-	11.5	-	800	3
10	-	-	51.5	1,448	-	-	-	-	-	-	1,200	0
11	-	-	190	4,390	0.7	16	0.4	9.2	28.6	615	2,250	0
12	-	-	40.2	893	-	-	-	-	-	-	3,000	5
13	11.2	172	180	2,742	0.5	7.6	0.3	4.6	14.4	219	3,500	3
	11.2	172	115	2,358	0.6	12	0.3	6.9	17.5	417	1,550	2

STA. NO. 5B

SAMPLING DATA

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	2,200	-
3	-	-	-	-	-	-	-	-	-	-	3,700	-
4	-	-	-	-	-	-	-	-	-	-	1,700	-
5	-	-	-	-	-	-	-	-	-	-	2,600	-
6	-	-	-	-	-	-	-	-	-	-	2,050	-
7	-	-	-	-	-	-	-	-	-	-	2,250	-
8	-	-	-	-	-	-	-	-	-	-	2,200	-
9	-	-	264	216	3.3	2.4	0.2	0.2	761	558	2,000	320
10	-	-	104	64	-	-	-	-	-	-	2,300	51
11	-	-	560	370	3.2	2.1	0.2	0.2	101	67	4,350	26
12	-	-	75.8	41	-	-	-	-	-	-	5,800	123
13	26.2	9	540	185	2.8	1	0.3	0.1	77.2	26	5,600	29
	26.2	9	315	175	3.1	1.8	0.3	0.2	313	217	3,093	110

STA. NO. 5C

SAMPLING DATA

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC COND	TURBIDITY
	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	CONC mg/l	LOAD kg/day	µmhos	J.T.U
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	1,100	-
3	-	-	-	-	-	-	-	-	-	-	1,900	-
4	-	-	-	-	-	-	-	-	-	-	900	-
5	-	-	-	-	-	-	-	-	-	-	1,400	-
6	-	-	-	-	-	-	-	-	-	-	1,100	-
7	-	-	-	-	-	-	-	-	-	-	1,150	-
8	-	-	-	-	-	-	-	-	-	-	1,200	-
9	-	-	82	-	0.7	-	0.1	-	47.4	-	800	2
10	-	-	60.7	1,751	-	-	-	-	-	-	1,250	0
11	-	-	230	5,466	1	24	0.4	9.5	40	951	2,400	0
12	-	-	41.9	954	-	-	-	-	-	-	3,100	25
13	11.3	176	230	3,582	0.9	14	0.3	4.7	22.6	352	4,500	0
	11.3	176	131	2,938	0.9	19	0.3	7.1	37	552	1,733	5

STA. NO. COMPOSITE

SAMPLING DATA

DATE	WEATHER CODE	FLOW	pH		ACIDITY		ALKALINITY		TOTAL IRON		FERROUS IRON		SULFATES		REF NO
		m^3/s	FIELD	LAB	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	
No Sample	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
11-20-73	F	2.727	5.4	7.6	0	-	48	11,301	0.43	101	0	0	200	47,091	2
1-09-74	F	-	6.7	6.4	12	-	102	-	2.01	-	-	-	350	-	3
2-12-74	F	-	5.3	6.0	6	-	99	-	2.18	-	-	-	200	-	4
3-27-74	F	-	5.7	6.4	2	-	134	-	1.69	-	-	-	275	-	5
4-30-74	F	-	7.0	7.2	0	-	156	-	0.7	-	-	-	650	-	6
5-23-74	R	-	-	7.0	0	-	148	-	1.2	-	-	-	350	-	7
6-12-74	F	-	-	7.4	0	-	206	-	1.4	-	-	-	425	-	8
6-24-74	F	-	-	6.6	18	-	80	-	2.5	-	-	-	200	-	9
7-08-74	F	-	-	7.2	0	-	166	-	1.1	-	-	-	550	-	10
7-22-74	F	-	-	7.4	0	-	143	-	0.9	-	-	-	475	-	11
8-04-74	F	-	-	6.6	8	-	182	-	1.3	-	-	-	550	-	12
8-21-74	F	-	-	7.2	0	-	144	-	1.8	-	0	-	550	-	13
Average		-	6.0	6.9	4	-	134	-	1.5	-	0	-	398	-	

STA. NO. COMPOSITE

SAMPLING DATA

REF NO	MAGNESIUM		CALCIUM		MANGANESE		ALUMINUM		SUSP SOLIDS		SPEC.	
	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	CONC mg/l	LOAD kg /day	CONC. mg/l	LOAD kg /day	COND. µmhos	TURBIDITY J.T.U.
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	700	-
3	-	-	-	-	-	-	-	-	-	-	1,300	-
4	-	-	-	-	-	-	-	-	-	-	650	-
5	-	-	-	-	-	-	-	-	-	-	790	-
6	-	-	-	-	-	-	-	-	-	-	1,000	-
7	-	-	-	-	-	-	-	-	-	-	900	-
8	-	-	-	-	-	-	-	-	-	-	1,200	-
9	-	-	79	-	0.4	-	0.7	-	39.6	-	500	25
10	-	-	54.8	-	-	-	-	-	-	-	1,100	11
11	-	-	300	-	0.3	-	0.1	-	24	-	1,600	1
12	-	-	40.7	-	-	-	-	-	-	-	2,600	16
13	11.2	-	240	-	0.2	-	0.1	-	16	-	2,700	0
	11.2	-	143	-	0.3	-	0.3	-	26.5	-	1,253	11